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THESIS

**CASE STUDIES OF PREDICTIVE ANALYSIS
APPLICATIONS IN LAW ENFORCEMENT**

by

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December 2015

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Law enforcement executives and policy makers continuously seek out effective strategies to reduce crime. Reducing crime reduces social harm, improves community resilience, and therefore improves homeland security. Before investing in a crime control strategy, police leaders must know if the effectiveness of that strategy has been validated. Predictive policing is one such strategy in use that relies on mathematical algorithms to forecast probable future crime locations and the application of interventions to interdict or prevent crime in those locations.

In this thesis, theories and methodologies behind predictive policing are described, and the case study method is used to review current predictive policing practices. The research finds that despite the conventional wisdom that a correlation exists between the implementation of a predictive policing program and a reduction in crime, no evidence indicates that a direct cause and effect relationship exists. This thesis provides law enforcement executives and policy makers with objective research on the effectiveness of predictive analysis in reducing crime and provides recommendations for those evaluating whether to invest time and resources into a predictive policing program.

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CASE STUDIES OF PREDICTIVE ANALYSIS APPLICATIONS IN LAW ENFORCEMENT

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Law enforcement executives and policy makers continuously seek out effective strategies to reduce crime. Reducing crime reduces social harm, improves community resilience, and therefore improves homeland security. Before investing in a crime control strategy, police leaders must know if the effectiveness of that strategy has been validated. Predictive policing is one such strategy in use that relies on mathematical algorithms to forecast probable future crime locations and the application of interventions to interdict or prevent crime in those locations.

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LIST OF ACRONYMS AND ABBREVIATIONS

BJA   Bureau of Justice Assistance

C3   Counter Criminal Continuum
CAD   computer-aided dispatch
COIN   counterinsurgency
CRU   Crime Response Unit

IED   improvised explosive device
ILP   intelligence led policing

MSP   Massachusetts State Police

NIJ   National Institute of Justice

PAI   Predictive Accuracy Index
PILOT   Predictive Intelligence Led Operational Targeting

RTM   risk terrain modeling

SCPD   Santa Cruz Police Department

UCR   Uniform Crime Reports

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EXECUTIVE SUMMARY

A.   INTRODUCTION

Police in the United States play a vital role in securing the homeland. Throughout the nation, police patrol a vast landscape ranging from densely populated urban communities to rural wilderness. Among their varied responsibilities, the reduction of crime is one that police leaders continuously strive to find improved methods by which to be successful. Reducing crime reduces social harm, improves community resilience, and strengthens homeland security. Improvements in technology and data collection have opened new avenues for police executives to pursue in crafting improved crime control strategies.

The use of mathematical algorithms to analyze data and predict where a crime is likely to occur is becoming more common in law enforcement. Often referred to as "predictive analysis," the term has become a buzzword within the profession, and some police agencies are attributing successes in their crime reduction efforts to the application of predictive analysis.

This research contributes to the homeland security enterprise by examining predictive analysis techniques within United States police agencies. The intent is to identify effective best practices and to establish recommendations for policy makers to refer to when considering crime-control policies in their jurisdictions and when evaluating an investment in a predictive analysis initiative.

B.   PROBLEM STATEMENT

Predictive analysis and predictive policing programs have not been widely studied from an objective, scientific perspective. While initial experiences by the agencies that have either fully implemented or experimented with predictive policing seem to be positive, predictive policing's impact on crime has yet to be definitively determined. It is a difficult problem, because the use of predictive analysis in policing is so new that little objective research has been conducted on its crime reduction applications, although many

practitioners claim to have had success in using predictive analysis to reduce specific crime problems in their jurisdictions.

This research looks at the problem critically and forms an unbiased conclusion that can guide the decision making of policy makers. Recommendations are given for policy makers to use when evaluating an investment in predictive analysis programs and/ or deciding what and how much historical data is necessary for use in predictive analysis programs.

This topic warrants further research because if predictive analysis can be validated as an effective practice, then law enforcement leaders will have a tool at their disposal that can improve their agencies' effectiveness at reducing crime and make better use of department resources, thus enhancing community safety. If not, time, money and effort could be wasted with no actual benefit realized. If effective, the resultant reductions in crime could improve community resilience and allow police departments to reallocate resources towards homeland security missions.

C.   RESEARCH QUESTIONS

The research question for this thesis is as follows. Is predictive analysis an effective crime control practice that can contribute to improved homeland security?

Secondary questions include the following. What is the relationship between predictive analysis and crime reduction in cities that have implemented the practice? How does the quantity and quality of historical data affect the relationship between predictive analysis and crime reduction?

D.   ANALYSIS

To determine the effectiveness of predictive policing, an objective analysis of the concept is warranted. Quantitative measures of crime should show improvement following the application of predictive analysis to crime problems to be considered effective. To test this hypothesis, case studies were conducted on municipal police departments in the United States, which included an examination of quantitative crime

data prior to, and following the implementation of a predictive policing program. In approaching this research, the extant literature on the subject was explored to evaluate the current body of knowledge on predictive policing. Further review was conducted to understand and inform the reader about the theoretical foundations behind predictive policing, and the use of predictive analysis in other fields outside of law enforcement. The review revealed that predictive policing takes many different forms, and that a number of different models and methodologies are available within the broader definition of predictive policing.

In subsequent chapters, case studies of predictive policing experiments in Santa Cruz, California; Shreveport, Louisiana; and Atlanta, Georgia are included as illustrations of various efforts that put predictive policing theory into practice. Each city employs a different approach with its predictive policing models. Evaluation of crime data for each of the case cities in this research failed to reveal a conclusive answer to the primary research question, despite claims from vendors and department representatives to the contrary.

This research project has not found the existence of a uniform, objective measurement of what constitutes an effective, or accurate predictive analysis technique. The scientific and academic community has not produced a standard metric by which to measure effectiveness.

E.   FINDINGS

One finding of this research is that predictive policing can clearly be broken down into two components, (1) Analysis of data to make crime predictions in terms of time and space, and (2) The application of the predictions by the police to conduct interventions in the specified locations. In recognition of these separate components, any objective study of predictive policing should not only include evaluating the predictive efficacy of whatever algorithm is being used, but the treatment and dosage applied by the police is a variable that should be studied as well.

The case studies demonstrated a mixed bag of improvement and worsening of crime associated with the various predictive policing experiments studied. What did not emerge from this study was a clear relationship between the quantitative measure of crime and predictive policing. Even in those circumstances in which a reduction in crime coincided with the application of predictive policing, the reduction in crime could not be more definitively connected to predictive policing than any other variable. What is most apparent from this research is that further study is needed to inform decision making fully in this area.

F.   RECOMMENDATIONS

Based on the research and findings for this thesis, the following recommendations are presented to guide future researchers studying the efficacy of predictive policing:

- Randomized controlled trials should be conducted by independent entities not having a proprietary interest in the outcome

- Conceive of metrics to measure effectiveness including, but not limited to measuring quantitative crime data. These metrics should include comparing interventions with outcomes, qualitative assessments of fear, and the use of community surveys to capture data indicative of the state of a community's resilience.

- Conceive of a method to study the impact of predictive policing in isolation from other factors that may also be impacting crime levels at the same time.

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I.   INTRODUCTION

Police in the United States play a vital role in securing the homeland. Throughout the nation, police patrol a vast landscape ranging from densely populated urban communities to rural wilderness. Their communities include features like residential neighborhoods, business districts, transportation facilities, critical infrastructure sites, parkland, and agricultural areas. Police officers are first responders to emergencies large and small, including natural and man-made disasters. Among their varied responsibilities, the reduction of crime is one that police leaders continuously strive to find improved methods by which to be successful. Reducing crime reduces social harm, improves community resilience, and strengthens homeland security. Improvements in technology and data collection have opened new avenues for police executives to pursue in crafting improved crime control strategies.

The use of mathematical algorithms to analyze data and predict where a crime is likely to occur is becoming more common in law enforcement. Often referred to as "predictive analysis," the term has become a buzzword within the profession, and some police agencies are attributing successes in their crime reduction efforts to the application of predictive analysis.[1]

The predictive analysis concept is illustrated in an IBM software commercial in which the camera switches back and forth between a police officer and a criminal. The officer is driving his patrol car glancing at his in-car computer display, while the criminal is driving down darkened urban streets in a beat-up sedan. The viewer sees both characters checking their wristwatches, and brief clips of a convenience store clerk preparing a night deposit bag. The commercial ends when the criminal arrives at the convenience store, putting on leather gloves as he exits his vehicle. The sequence leads the viewer to believe that the criminal intends to rob the store, but as he approaches the entrance, the camera reveals the police officer leaning on his car in the parking lot,

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[1] Rick Whiting, "Predict the Future-Or Try, Anyway," *Information Week*, May 29, 2006, ProQuest; James Vlahos, "The Department of Pre-Crime," *Scientific American* 306, no. 1 (2012): 62–67, doi:10.1038/scientificamerican0112-62.

drinking a cup of coffee. His robbery plans thwarted, the criminal turns and walks away in frustration. The narrator declares that analyzing crime data, spotting patterns, and figuring out where to send patrols, has helped some U.S. cities cut serious crime by up to 30 percent.[2] The viewer is left with the impression that by using IBM's predictive analysis software, police can see the future; enabling them to predict the location of a future crime, and arrive there before the offender does.

Notwithstanding the IBM commercial, predictive analysis is not a crystal ball with which police can see the future, but the use of analytical techniques appears to correlate with a reduction in crime in some communities. This research contributes to the homeland security enterprise by examining predictive analysis techniques within U.S. police agencies. The intent is to identify effective best practices and to establish recommendations for policy makers to refer to when considering crime-control policies in their jurisdictions and when evaluating an investment in a predictive analysis initiative.

A.   PROBLEM STATEMENT

The purpose of this thesis is to provide policy makers with objective research into the effectiveness of predictive analysis as a crime-fighting tool and identify whether the practice is worth the investment of time and resources in order to reduce crime, enhance community resilience, and contribute to improved homeland security. It is a difficult problem, because the use of predictive analysis in policing is so new that little objective research has been conducted on its crime reduction applications, although many practitioners claim to have had success in using predictive analysis to reduce specific crime problems in their jurisdictions.

Predictive analysis is in use today in many police departments as part of a strategy known as "predictive policing" to forecast probable future crime locations and then apply interventions to interdict or prevent crime in those locations. The accuracy of the analysis seems to be dependent on the quality and quantity of historical data available for

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[2] "Predictive Analytics-Police Use Analytics to Reduce Crime," You Tube video, 0:33, posted by IBM, published March 27, 2012, http://youtu.be/_ZyU6po_E74.

analysis.[3] Analytical software vendors, police officials, and some academics strongly assert the effectiveness of the use of these types of software applications.[4] Others advocate being cautious in their expectations of what predictive analysis can do.[5] While a correlation appears to exist between the implementation of the predictive analysis programs and a reduction in crime, no evidence indicates that a direct cause and effect relationship exists. The impact of other factors, such as demographics, economics, and an array of other social factors, should be considered in evaluating the cause of reduced crime in any particular jurisdiction.[6]

This research looks at the problem critically and forms an unbiased conclusion that can guide the decision making of policy makers. Recommendations are given for policy makers to use when evaluating an investment in predictive analysis programs and/ or deciding what and how much historical data is necessary for use in predictive analysis programs.

The relationship between the quality of data being analyzed, and the impact of that data on the quality of analysis is examined as well. A critical question that needs to be answered is the following. What types of data need to be collected and assessed to support predictive policing practices?

This topic warrants further research because if predictive analysis can be validated as an effective practice, law enforcement leaders will have a tool at their disposal that can improve their agency's effectiveness at reducing crime and make better use of department resources, thus enhancing community safety. If not, time, money and effort could be wasted with no actual benefit realized. To determine the effectiveness of predictive policing, an objective analysis of the concept is warranted. Quantitative measures of crime should show improvement following the application of predictive analysis to crime problems to be considered effective. To test this hypothesis, case

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[3] Whiting, "Predict the Future-Or Try, Anyway"; Walter L. Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations* (Santa Monica, CA: RAND Corporation, 2013), xiii, http://www.rand.org/pubs/research_reports/RR233. Also available in print form.

[4] Vlahos, "The Department of Pre-Crime."

[5] Perry et al., *Policing: The Role of Crime Forecasting in Law Enforcement Operations*.

[6] Vlahos, "The Department of Pre-Crime."

studies were conducted on municipal police departments in the United States, which included an examination of quantitative crime data prior to, and following the implementation of a predictive policing program.

It is the intent of the author that readers of this thesis will learn more about the practice of predictive analysis that will serve as a guide to better policy decisions. It is also the author's intent to contribute to a larger body of knowledge about the subject that could be useful to others.

B.   RESEARCH QUESTIONS

This thesis evaluates whether a potential benefit exists from applying predictive analysis to homeland security problems. The use of predictive analysis is expanding as a crime-reduction strategy, but before its effectiveness in homeland security can be considered, its effectiveness in the criminal justice applications currently in use should be evaluated.

The intent of this thesis is to inform readers about the effectiveness of predictive analysis so they may make informed decisions regarding the practice before they invest the time and resources of their organization into establishing a predictive analysis strategy.

The research question for this thesis is as follows. Is predictive analysis an effective crime control practice that can contribute to improved homeland security?

Secondary questions include the following. What is the relationship between predictive analysis and crime reduction in cities that have implemented the practice? How does the quantity and quality of historical data affect the relationship between predictive analysis and crime reduction?

C.   SIGNIFICANCE OF RESEARCH

The application of predictive analysis techniques by police departments within the United States warrants study because, if effective, the resultant reductions in crime could improve community resilience and allow police departments to reallocate resources towards homeland security missions.

D.   COMMUNITY RESILIENCE

Police departments spend a considerable amount of time and resources patrolling their respective jurisdictions, investigating crimes, responding to calls for service, and arresting offenders. The ultimate goal of these activities is to reduce the chances that citizens will become crime victims, as well as the overall crime rate. This thesis asserts that reducing crime reduces social harm, thus improving community resilience. Community resilience is a homeland security priority, and by improving a community's resilience, homeland security is improved. As an added benefit, police would gain the ability to refocus their work on other homeland security issues, such as terrorism, due to the reduced focus on crime.

Naval Postgraduate School graduate John A. Bennett, Jr. best describes this assertion, "Local law enforcement agencies' role in combating terrorism should center on crime reduction. The crime fighting energy recovered from lowering crime can be converted to proactive efforts, which can root out precursor acts related to the planning and execution of domestic and international terrorism as an operational byproduct."[7]

The nexus between law enforcement and counterterrorism has been clearly established.[8] Intelligence-Led Policing (ILP), of which predictive policing is a subset,[9] is an important policing concept that can be applied to both crime reduction and counterterrorism. Integrating the counterterrorism, intelligence, and crime prevention missions of a police agency enhances public safety.[10] It is also true that while endeavoring to reduce crime, police may incidentally interrupt terrorists who are

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[7] John A. Bennett Jr., "Combating Terrorism within Local Policing through Crime Reduction: Using Real-Time, Situational Awareness within a Distributed Common Operating Picture to Combat All Crime and Terrorism–V2i2sion Process and Safecop Pilot Project," 2013, http://calhoun.nps.edu/public/handle/ 10945/32793.

[8] Dean C. Alexander and Terry Mors, "Best Practices in Identifying Terrorists during Traffic Stops and on Calls for Service," *Crime and Justice International* 23, no. 99 (2007): 4.

[9] Charlie Beck and Colleen McCue, "Predictive Policing: What Can We Learn from Wal-Mart and Amazon about Fighting Crime in a Recession?," *Police Chief Magazine*, November 2009.

[10] John E. Ball, "Rethinking Intelligence to Integrate Counterterrorism into the Local Law Enforcement Mission" (master's thesis, Naval Postgraduate School, 2007), http://calhoun.nps.edu/ public/handle/10945/3656.

committing crimes that are precursor acts to a terrorist operation.[11] It has also been established that local law enforcement has a clear role "in counter terrorism and in the process of developing and sharing intelligence about terrorist threats."[12]

As discussed later, crime tends to concentrate in relatively few locations, while the remaining areas remain relatively crime free.[13] As police work towards improving community resilience by reducing crime, they should be mindful of the importance of reducing citizen fear of crime as well. Reducing crime in these concentrated locations can reduce fear over a broader landscape, with an accompanying broader benefit towards community resilience, and thus, homeland security.

Violent and property crime in the United States has been steadily declining for decades.[14] What is often overlooked, however, is the level of fear felt by citizens in regards to their own personal safety. It is often the case that citizen fear, or perception, does not correspond with a reduction in crime.[15] While fear is an intangible experience that does not directly result in bodily injury or loss of property, fear can have a negative impact on community resilience if it is ignored.[16] Resilience is defined by The Department of Homeland Security as "the ability to adapt to changing conditions and prepare for, withstand, and rapidly recover from disruption."[17] If a community's level of fear is out of proportion with actual risk, the community's ability to withstand

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[11] Bennett Jr., "Combating Terrorism within Local Policing through Crime Reduction."

[12] Cathy L. Lanier, "Preventing Terror Attacks in the Homeland a New Mission for State and Local Police" (master's thesis, Naval Postgraduate School, 2005), http://calhoun.nps.edu/public/handle/10945/1957.

[13] Anthony Allan Braga and David Weisburd, *Policing Problem Places: Crime Hot Spots and Effective Prevention* (Oxford: Oxford University Press, 2010).

[14] "Crime in the U.S.," accessed December 28, 2014, http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s.

[15] Ralph B. Taylor and Margaret Hale, "Testing Alternative Models of Fear of Crime," *Journal of Criminal Law and Criminology* 77, no. 1 (1986): 151–89; Kerry Burke, Edgar Sandoval, and Jonathan Lemire, "NYPD Crime Statistics Say New York City Is Safer, but Many Worry Economy Is Spurring Crime Surge," *New York Daily News*, May 26, 2009, http://www.nydailynews.com/news/crime/nypd-crime-statistics-new-york-city-safer-worry-economy-sparking-crime-surge-article-1.374787.

[16] Gary Cordner, *Reducing Fear of Crime: Strategies for Police* (Washington, DC: U.S. Department of Justice, Office of Community Oriented Policing Services, 2010).

[17] "Resilience," accessed December 27, 2014, http://www.dhs.gov/topic/resilience.

disruptions, adapt, and recover from disasters like major storms or terrorist attacks might be compromised.

Police leaders should embrace the reduction of community *fear* of crime as part of their agencies' missions and incorporate evidence-based approaches to reducing fear of crime in addition to their traditional mission of reducing actual crime.

Similar to terrorism, crime directly affects a limited number of people when compared to the overall population.[18] The majority of crime in the United States is concentrated in a minimum of locations, and is committed by a minimum percentage of the population. It is known that crime and disorder concentrate in small clusters, or "hot spots," that the majority of crime takes place in a small percentage of places, and that most other areas are relatively crime free.[19] Studies have shown that focusing police activity in these hot spots can be effective at preventing or reducing crime,[20] yet the fear engendered by crime has more widespread effects.

One model used to explain the link between crime and fear is the indirect victimization perspective.[21] One of the major points of this model is that a criminal event has a broader impact than only on the victim of the actual crime. Taylor and Hale explain, "a criminal event sends out shock waves that spread throughout the community via local social networks."[22] This phenomenon has an amplification effect that spreads fear among other members of the community who did not experience the crime directly. As people learn of the crime and relay the story to others, the waves propagate, creating secondary victims.

It is important to note the role of negativity bias on human thinking. Humans react more strongly to events or circumstances that have a negative impact than those that have

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[18] "Crime in the U.S."

[19] Braga and Weisburd, *Policing Problem Places*.

[20] Anthony Braga, "The Effects of Hot Spots Policing on Crime" (The Campbell Collaboration, June 27, 2012), http://campbellcollaboration.org/lib/project/24/.

[21] Taylor and Hale, "Testing Alternative Models of Fear of Crime."

[22] Ibid.

a positive impact; thus, bad news has a greater impact than good news.[23] It is believed that humans developed a greater sensitivity to negative experiences as a survival mechanism. The brain "developed systems that would make it unavoidable for us not to notice danger and thus, hopefully, respond to it."[24] Marano writes that the impact of negative experiences is five times more powerful than that of positive experiences.[25] Thus, it takes a ratio of five positive experiences to outweigh the impact of one negative experience.

Within the context of crime, it means that it is a major challenge to mitigate the impact of a single crime and restore/reduce citizen fear levels. It also true that if police leaders can meet the challenge of negative bias, then their efforts can have a positive effect on fear.

Fear is not always a reflection of actual crime levels. Crime has been falling consistently for over a decade, but that reduction is not matched by a likewise reduction in fear.[26] This gap between falling crime rates and the level of fear is referred to as the reassurance gap.[27]

Some arguments can be made that fear reduction is not the job of the police. One such argument is that fear is an emotion, or a perception that is too intangible on which the police can have a meaningful impact. The counterarguments to this position are far stronger.

Modern policing is considered to date back to 1829 when the London Metropolitan Police force was established.[28] British Home Secretary Sir Robert Peel, in attempting to define an ethical police force, set out nine principles of policing that are

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[23] Hara Estroff Marano, "Our Brain's Negative Bias," *Psychology Today*, June 20, 2003, http://www.psychologytoday.com/articles/200306/our-brains-negative-bias.

[24] Ibid.

[25] Ibid.

[26] Burke, Sandoval, and Lemire, "NYPD Crime Statistics Say New York City Is Safer, but Many Worry Economy Is Spurring Crime Surge."

[27] Cordner, *Reducing Fear of Crime: Strategies for Police*.

[28] "Metropolitan Police," accessed December 27, 2014, http://www.parliament.uk/about/living-heritage/transformingsociety/laworder/policeprisons/overview/metropolitanpolice/.

still considered foundational pillars in Anglo-American policing. These principals persist, as illustrated by New York City Police Commissioner William Bratton's use of them to guide the largest police department in the United States. The first of these principles is "The basic mission for which the police exist is to prevent crime and disorder."[29]

Present day experts on policing echo Peel's principles. Moore and Braga established "seven dimensions of value" to describe what police departments are supposed to achieve.[30] Included in those dimensions is reducing fear of crime:

> Citizens react to *signs* of disorder—things that they associate with increased risk, such as public drunkenness, prostitutes openly soliciting, and rowdy groups—rather than to real objective risks of victimization. Furthermore … police can do things that are successful in reducing fear *even if they leave the objective risks untouched.* [emphasis in original] *...* reducing crime turns out to be somewhat disconnected from enhancing the sense of security that citizens feel.

> …the subjective experience of security from criminal attack is one of the most important ultimate objectives of the police. We want the police to produce a sense of security as well as the reality of reduced risk of criminal victimization. If they produce real, objective security, but leave us feeling afraid, they have not accomplished what we really want them to do—allow us to go about our lives with a reasonable degree of security. Further, the relationship between reduced crime on one hand and increased security on the other is complex, not simple.[31]

Northwestern University researcher Wesley Skogan writes that fear of crime contributes to disorder in the form of negative impacts on communities, such as lack of citizen participation, reduction in the value of residential property, and reduced viability of businesses, and overall reduced quality of life.[32]

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[29] "Sir Robert Peel's Nine Principles of Policing," *New York Times*, April 15, 2014, http://www.nytimes.com/2014/04/16/nyregion/sir-robert-peels-nine-principles-of-policing.html.

[30] Cordner, *Reducing Fear of Crime: Strategies for Police*.

[31] Ibid., quoted in Mark H. Moore and Anthony Braga, *The "Bottom Line of Policing"* (Washington, DC: Police Executive Research Forum (PERF), 2003).

[32] Wesley G. Skogan and Michael G. Maxfield, *Coping with Crime: Individual and Neighborhood Reactions* (Thousand Oaks, CA: Sage Publications 1981), https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=78899.

Police leaders need to be cognizant of what can happen if they do not attempt to reduce fear of crime. Fear creates pressure on police leaders to commit resources to address perceptions of crime rather than on actual problems. Failing to address fear can reduce public confidence in the police and their leadership. An atmosphere of fear negatively impacts community resilience, which is a homeland security problem because community resilience is an essential component in strengthening a community against major disasters.

What can the police do to reduce the perception of fear? As has been shown, merely reducing crime does not have a direct correlation with reduced fear.[33] Accordingly, the objective should be defined as not to eliminate fear completely, but to balance fear commensurate with actual risk. It is important to acknowledge that it is rational to take precautions against crime and not to be complacent, as a complete absence of fear could make a citizen more vulnerable.

In formulating fear reduction strategies, police leaders must take a problem-oriented approach. The root cause of citizens' fear can vary and must be identified. Implementing a community policing philosophy and engaging with citizens is a crucial step in identifying what the contributing factors to fear are. The evidence shows that increased police/community contact improves citizen perceptions of the police and can contribute to a feeling of safety.[34] Police leaders must exploit this community engagement to drill down further and determine, in greater detail, what strategies should be employed to reduce fear. Citizen feedback may reveal that fear is caused by lack of police visibility; which can be remedied with increased foot or other patrols in the affected area. Quality of life issues, such as public drunkenness or graffiti, may cause fear, which police can address with enforcement and other interventions. These issues are only a few of a host of contributing factors that can only be revealed through increased interaction between the police and the community they serve.

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[33] Taylor and Hale, "Testing Alternative Models of Fear of Crime"; Burke, Sandoval, and Lemire, "NYPD Crime Statistics Say New York City Is Safer, but Many Worry Economy Is Spurring Crime Surge."

[34] Cordner, *Reducing Fear of Crime: Strategies for Police*.

Considering the impact of fear of crime on a community may at first appear to be unrelated to the homeland security enterprise. It is easy to view crime as a relationship solely between the offender and intended victim(s). A broader view reveals that criminal activity and the *fear* of criminal activity is a consumer of police resources. These very same resources are also tasked with protecting communities from terrorism, and as first responders to disasters, such as storms, accidents, and earthquakes. Police have a role in the prevention, preparedness, response, and mitigation of significant events, as well as in contributing to community resilience. Fear of crime spreads beyond the initial victim, which weakens the fabric of a community, and thus, weakens its resilience. To further the homeland security enterprise, police should make a concerted effort to reduce the fear of crime in their communities as they carry out their mission of preventing crime and disorder.

This thesis provides a critical analysis of the relevant literature, describes the theories behind predictive policing, the various scientific methods in use for making crime predictions, and provides case studies of actual jurisdictions that have incorporated predictive policing into their operational philosophy. The findings of the case studies are described and recommendations for future research, as well as recommendations for police executives considering an investment in predictive policing, are provided.

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II.   LITERATURE REVIEW

Police agencies in the United States are investing in predictive analysis as a crime control strategy. If effective, predictive analysis could contribute to improved homeland security by improving community resilience. For police executives and policy makers to make intelligent and informed decisions regarding predictive analysis, it is important for the practice to be validated in an objective, scientific manner. This literature review was conducted with the following question in mind. Has predictive policing been validated as an effective method of reducing crime?

To conduct the research for this thesis, the existing literature on predictive policing and predictive analysis was reviewed. The sources for this research consisted of books, periodicals, professional journal articles, and various government and academic web pages. Since a limited body of work addresses the causal relationship between predictive analysis and crime reduction, the review was broadened to include the use of data and analytics in the business world, counterterrorism, and the military.

To understand what the police can do to reduce crime, the literature review also included work relating to the various theories of crime causation. Such theories are relevant when considering crime reduction strategies, because to influence crime, policy makers must have an understanding of what is known in this area of study. It is also important to understand what other police practices might have a beneficial impact on crime to provide necessary context and background when assessing predictive policing. Predictive policing programs in use in specific police departments within the United States were also examined, and studies of these programs were consulted to determine if crime reductions were causally related to these individual programs. This literature review also sought to ascertain what types of crime predictive policing might be effective against, and if the methodology of predictive policing could be applied to predicting or forecasting potential active shooter attacks.

The literature review has been organized into six areas related to predictive policing. The first section provides background and attempts to identify a standard

definition of predictive policing. The second section focuses on literature pertaining to theories of crime causation. The following two sections examine the literature pertaining to the use of predictive analytics in business, and law enforcement applications. The fifth section focuses on other non-business, non-police related research related to predictive analysis. Finally, the sixth section discusses research related to whether predictive analysis could be applied to predicting active shooter or other types of violent lone-offender attacks.

A.   BACKGROUND

This research first attempted to establish a definition of predictive policing. Within the criminal justice field, predictive policing appears to be an extension of intelligence led policing (ILP). Dr. Jerry Ratcliffe, of Temple University has written extensively about ILP, predictive policing, and predictive analysis. His book, *Intelligence Led Policing*, published in 2008, is frequently cited in other literature.[35] The book describes the various aspects of ILP and its adaptation from the original UK model.

Within the strategy of intelligence led policing is the "predictive policing" approach. The practice of trying to identify future crime trends has been a law enforcement practice since about 2008.[36] In 2009, The National Institute of Justice (NIJ) and the Bureau of Justice Assistance (BJA) hosted a symposium in Los Angeles focused on predictive policing. One focus of the symposium was the issue of defining what predictive policing is.[37]

Practitioners and scholars use varying definitions of the term "predictive-policing." Predictive policing has been described by Los Angeles Police Chief Charlie Beck and academic Dr. Colleen McCue as the next era in policing; following the professional policing era of the 1960s, the community policing era of the 1990s, and the

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[35] Jerry Ratcliffe, *Intelligence-Led Policing* (London and New York: Willan Publishing, 2008).

[36] Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations*, xiii.

[37] Pearsall, "Predictive Policing: The Future of Law Enforcement," 16–19.

ILP era of the post-9/11 world.[38] They describe predictive policing as an enhancement of ILP that can improve crime reduction efforts without abandoning the benefits of the community-policing era.[39]

Perry et al. describe predictive policing as "the application of analytical techniques—particularly quantitative techniques—to identify likely targets for police intervention and prevent crime or solve past crimes by making statistical predictions."[40] NIJ Deputy Director, John Morgan, defines it as "any policing strategy or tactic that develops and uses information and advanced analysis to inform forward-thinking crime prevention."[41] Author Beth Pearsall defines predictive policing as "taking data from disparate sources, analyzing them and then using results to anticipate, prevent and respond more effectively to future crime."[42]

Based on the literature, it is apparent that predictive analysis is a component of predictive policing that applies mathematical algorithms to data in an attempt to forecast future trends. The terms "data mining" and "predictive analysis" are closely related. Merriam-Webster's defines data mining as the "practice of searching through large amounts of computerized data to find useful patterns and trends."[43] McCue differentiates between two forms of data mining, predictive and descriptive; both being forms of predictive analysis.[44] Dr. John Hollywood, co-author of the aforementioned RAND

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[38] Beck and McCue, "Predictive Policing: What Can We Learn from Wal-Mart and Amazon about Fighting Crime in a Recession?".

[39] Ibid.

[40] Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations*.

[41] Morgan, as quoted by Craig D. Uchida, *A National Discussion of Predictive Policing: Defining Our Terms and Mapping Successful Implementation Strategies* (Washington, DC: National Institute of Justice, 2009).

[42] Beth Pearsall, "Predictive Policing: The Future of Law Enforcement?" *NIJ Journal* 266 (2010): 16–19.

[43] "Data Mining," accessed November 2, 2013, http://www.merriam-webster.com/dictionary/data mining.

[44] Colleen McCue, *Data Mining and Predictive Analysis: Intelligence Gathering and Crime Analysis* (Oxford: Butterworth-Heinemann, 2006).

report, offered his law enforcement oriented definition of predictive analysis as "data mining combined with actions taken to reduce crime."[45]

Predictive analysis involves using computer software to apply mathematical algorithms to historical data in an attempt to forecast future crime trends. The data collected goes beyond time, place, and offender information. Information, such as weather, upcoming paydays, distances from ATMs and bars, are examples of the types of data that can be analyzed as part of the practice.[46] In theory, if ILP allows agencies to deploy resources where most crimes are committed, predictive policing allows agencies to deploy resources where crimes are most likely to occur at a future time. If predictive policing is an effective model, it can allow agencies to place police officers in the right places strategically at the right time; thereby, making the best use of limited resources. If predictive analysis is found to not be effective, an organization's resources, focus, and mission may be adversely affected.

What is common among the various definitions of predictive policing is the emphasis on future crime.

B.   THEORIES

To understand how predictive analysis might work in law enforcement, it is necessary to understand also the prevailing theories of crime causation. Numerous scholars have studied and written on this matter.

Rational choice theory is discussed frequently in literature about crime prediction and forecasting. Rational choice theory posits, "all criminal decision-making is based on some amount of rationality."[47] Offenders are "influenced by situational and environmental factors that provide desirable or undesirable offending opportunities."[48]

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[45] Jerry H. Ratcliffe et al., "Predictive Analytics: Theories and Practices" (paper presented at 120th International Association of Chiefs of Police Conference, Philadelphia, PA, October 21, 2013).

[46] Vlahos, "The Department of Pre-Crime," 2012; McCue, *Data Mining and Predictive Analysis.*

[47] Jennifer Bachner, *Predictive Policing: Preventing Crime with Data and Analytics* (IBM Center for the Business of Government, 2013), http://www.businessofgovernment.org/report/predictive-policing-preventing-crime-data-and-analytics.

[48] Elizabeth R. Groff and Nancy G. La Vigne, "Forecasting the Future of Predictive Crime Mapping," *Crime Prevention Studies* 13 (2002): 29–58.

"By collecting and analyzing data on these features, police can mimic an offender's target selection and theoretically thwart a crime prior to its occurrence."[49]

Further supporting the ability to forecast crime is repeat victimization theory; locations and individuals that have been previous targets of crime are likely to be targeted again.[50] Repeat victimization theory is dependent on accurate historical crime data to determine what individuals or locations are likely to become targeted again.

Etchison concludes that there is "no single answer to the question, "What causes crime?" and that further research is necessary to "define and identify the limits of predictive tools, and the development of an overarching theory of crime which can synthesize the individual-, society-, and law enforcement system-based theories."[51] Even in the presence of such a theory, Etchison believes it lacks the power to "pinpoint the individuals who will commit specific crimes."[52]

The review of the literature revealed that the use of maps to record the locations of crimes dates back to the early 1800s in France.[53] Sporadic use continued until well into the 20th century but never reached a point where the use of crime maps was sustained or widespread. This sporadic use was due in part to limitations in technology, lack of recognition of the relevance of such maps, access to computers, and the lack of capability in collecting and storing data, as well as the ability to match data to maps.[54] Over time, computerized records management systems, which allow police departments to record and store crime data, have become more common, thus improving the availability of relevant data for mapping.

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[49] Bachner, "Predictive Policing: Preventing Crime with Data and Analytics."

[50] Ibid.; Graham Farrell and William Sousa, "Repeat Victimization and Hot Spots: The Overlap and Its Implications for Crime Control and Problem-Orientated Policing," *Crime Prevention Studies* 12 (2001): 221–40.

[51] J. C. Etchison, "Theories of Crime Causation," *Policy Studies Journal* 3, no. 1 (September 1974): 7–12.

[52] Ibid.

[53] David Weisburd and Tom McEwen, *Crime Mapping and Crime Prevention* (Monsey, NY: Criminal Justice Press, 1998).

[54] Ibid.

Groff and La Vigne note that most mapping applications to date have been "retrospective;" mapping the locations of crime and related factors that have occurred in the past.[55] In predictive policing, the true value of mapping lies in the ability to identify locations of future crime or "hot spots."

C.   PREDICTIVE ANALYSIS IN THE BUSINESS WORLD

The literature demonstrates that predictive analytics have been in use within the business community for many years before law enforcement. Studies were found dating to the 1970s in which predictive analytics were studied by academics to propose geographic models for retail market shape to predict consumer behavior.[56] Others modeled consumer behavior to predict what stores would be chosen by patrons in shopping centers.[57] The credit industry uses predictive analysis to drive corporate decision making to maximize profits and assign credit scores to consumers.[58] The availability of large volumes of data has made business intelligence and analytics of great interest to the business and academic communities in the 21st century.[59] The literature included specific cases in which Walmart, Amazon, and the Walt Disney Company use predictive analytics in their respective operations.

D.   LAW ENFORCEMENT APPLICATIONS

No standardized model of predictive policing is available. In 2013, the RAND corporation published a report titled, *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations.* The report concluded that predictive analysis could

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[55] Groff and La Vigne, "Forecasting the Future of Predictive Crime Mapping."

[56] J. Barry Mason, "Retail Market Area Shape and Structure: Problems and Prospects," *Advances in Consumer Research* 2, no. 1 (January 1975): 173.

[57] Melvin R. Crask, "A Simulation Model of Patronage Behavior within Shopping Centers," *Decision Sciences* 10, no. 1 (January 1979): 1–15.

[58] Collette Land, "The Power of Predictive Analytics," *Credit Management*, December 2, 2006, 12–15; Whiting, "Predict the Future-Or Try, Anyway."

[59] Hsinchun Chen, Roger HL Chiang, and Veda C. Storey, "Business Intelligence and Analytics: From Big Data to Big Impact.," *MIS Quarterly* 36, no. 4 (2012), http://search.ebscohost.com/login.aspx?direct= true&profile=ehost&scope=site&authtype=crawler&jrnl=02767783&AN=83466038&h=7OlQMXoL1qrJ3 1m3%2FMaAtQ0gADgZ7JWseTKbP14GdBSeWYAE4xXJsD3ON9pvSGHFSHfOx9tniPXX%2BMaOgE VTkQ%3D%3D&crl=c.

"allow police to work more proactively with limited resources."[60] According to Telep et al., of The Center for Evidence Based Crime Policy at George Mason University, proactive policing methods are most effective at reducing violent crime.[61]

The RAND researchers identified four broad categories of predictive methods in use to forecast places vulnerable to crime, persons at risk of offending in the future, likely offenders of past crimes, and potential victims of crimes.[62]

Based on a review of the RAND report and other literature reviewed, it appears that the most common forms of predictive policing in use are those in the first category, commonly known as "place based" methods. These methods analyze past crimes and characteristics of places where crimes have occurred. Through this analysis, hot spots can be identified for further intervention, such as directed, high-visibility patrols to deter crime, or discreet surveillance to interdict and arrest offenders.

A number of American cities have implemented predictive analysis programs to address specific crime problems. Various articles in professional journals and publications were found that describe the results of these programs, and attribute reduced crime in those jurisdictions to the predictive analysis programs. The results of a number of the police department predictive analysis programs studied were described as having a significant impact on reducing violent crime. While these articles attribute the reduced crime to the predictive analysis programs, academic research has yet to be located that substantiates this correlation as having a direct cause and effect relationship. As researcher James Vlahos points out, the causes of crime are complex, and the relationships between the various contributing factors are not fully understood.[63] In fact, the crime reductions experienced in the jurisdictions using predictive analysis correlate with a nationwide drop in crime, including in communities without predictive analysis programs.

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[60] Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations*.

[61] Cody W. Telep, *Police Interventions to Reduce Violent Crime: A Review of Rigorous Research* (Fairfax, VA: Center for Evidence-Based Crime Policy, George Mason University, 2009).

[62] Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations*, xiii.

[63] Vlahos, "The Department of Pre-Crime," 62–67.

Some wariness also arises among some academics regarding the ability to predict future crime. At a conference in October, 2013, Ratcliffe stated that he was suspicious of the term "predictive," and cautioned police executives not to rush into purchasing expensive software suites that promised to foretell the times and places of future crimes.[64] He described predictive analysis as more of a vulnerability analysis, and stated that the "prediction" comes in knowing what characteristics make a place vulnerable to crime, not forecasting.[65] This "vulnerability analysis" identifies places that tend to attract crime clusters before they form, which helps police develop interventions to mitigate the environmental risks that make the location vulnerable to crime.[66] One of Ratcliffe's co-presenters, John Hollywood, was also co-author and project leader of the RAND report cited earlier. Hollywood echoed both the report, and Ratcliffe's comments, by stressing that the effectiveness of predictive analysis relies on the type of intervention taken by police to mitigate the factors identified by the analysis.

Based on these varied opinions, it is evident that more research is needed in this area to substantiate the impact of predictive analysis on crime, but enough of a correlation appears to exist to at least consider predictive analysis as a promising crime reduction tool. This literature review found scant academic research or controlled experiments available into the effectiveness of the various predictive policing methods in use. While a definite correlation appears to exist between the applications of predictive techniques, many academics agree that this field is still in its development and that further research is warranted.[67]

E.   OTHER APPLICATIONS

Further research was conducted to evaluate whether these same promising techniques could also have application within the homeland security domain. Some

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[64] Ratcliffe et al., "Predictive Analytics: Theories and Practices."

[65] Ibid.

[66] Ibid.

[67] Groff and La Vigne, "Forecasting the Future of Predictive Crime Mapping."

studies have been published that do indicate that predictive value exists in certain analytical programs that could pertain to homeland security.

A mathematical algorithm developed by researchers Benigni and Furrer was tested in 2007 and 2008 to determine its effectiveness in predicting improvised explosive devices (IEDs) along specified convoy routes in Iraq.[68] Their research determined that the model had "predictive power in the short term,"[69] as long as no major changes in battlefield conditions occurred, such as the denial of territory to the enemy. This predictive capability could be useful to commanders involved in convoy route planning. The ability to use predictive analysis to forecast the route least likely to harbor an IED emplacement could potentially save lives.

For approximately five months during 2006, the RAND-developed "actionable hot spot" concept was tested to determine its effectiveness at predicting the locations of IED emplacements targeting troops in Iraq.[70] Software was used to analyze historical data on previous IED emplacements in an effort to forecast future emplacements. These forecasts were then used to guide interventions, such as sending in sniper teams or conducting surveillance of the forecast locations. The units studied were able to predict IED locations accurately 30 percent of the time during the test period of August 1 through December 23, 2006 by using the predictive analysis technique. This detection rate is reported to be considerably more accurate than not applying the technique.[71]

Both studies were place-based analyses that attempted to determine the most likely locations that an attack would occur. Both bear resemblance to the place-based techniques used by the police departments previously cited that attempted to determine the most likely locations, or hot spots, of crime.

Research into using vulnerability analysis to predict terrorist target selection was also reviewed. Researcher Ferenc Jordan of the Collegium Budapest, Institute for

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[68] Matthew Benigni and Reinhard Furrer, *Periodic Spatio-Temporal Improvised Explosive Device Attack Pattern Analysis* (technical report Mcs-04-08) (Golden, CO, Colorado School of Mines, 2008).

[69] Ibid.

[70] Perry et al., *Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations*.

[71] Ibid.

Advanced Study, studied the London underground bombings of 2005 and conducted a vulnerability analysis of the underground networks of London, Tokyo, and Budapest. Jordan's findings were that network analysis has value in predicting the locations of specific terrorist targets, which would aid in prioritizing homeland security resources.[72] This finding bears similarity to the strategy of identifying crime hot spots. Jordan states that the value of his analysis resides in predicting the vulnerability of targets, rather than the time and place of an actual attack.[73]

F.   ACTIVE SHOOTERS

Literature pertaining to single-offender crimes, such as lone wolf terrorism or active shooter attacks, was reviewed to determine if predictive analysis could be applied to prevent such an attack.

Longitudinal studies by the New York City Police Department and the FBI on active shooter attacks in the United States were reviewed, as well as a study on rampage school shootings conducted by the Washington State Fusion Center and the Oregon TITAN Fusion center. These studies compiled a dataset of active shooter attacks including characteristics of the locations attacked, offender characteristics, number of attackers, method of attack, and a host of other factors. From these compilations, it is possible to form a picture of what the most common characteristics of an attacker are. For instance, the 2014 FBI study, while not specifically focused on shooter motivation, demonstrated that a majority of active shooters in the United States are male, and act alone. While useful, such information is not in itself predictive of who will conduct an attack or when one will occur.

Kebbell and Porter studied whether a risk assessment model could be created that could identify individuals motivated by violent extremism that might be at risk of

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[72] Ferenc Jordan, "Predicting Target Selection by Terrorists: A Network Analysis of the 2005 London Underground Attacks," *International Journal of Critical Infrastructures* 4, no. 1 (January 1, 2008): 206–14, doi:10.1504/IJCIS.2008.016101.

[73] Ibid.

attacking Western targets.[74] The study concluded that a number of factors appear to be associated with risk of violent extremism,[75] but there is "not sufficient evidence to create a risk assessment model to predict who is intending to commit violent extremism and distinguish them from those who are not."[76]

The literature on single-offender active shooter and lone wolf attackers seems to point to the fact that known individuals can be assessed for their potential for violence based on evaluating their behavior and conduct. What is also apparent from the literature is that absent a known individual to evaluate, an active shooter attack is not possible to predict using mathematical algorithms alone. An area for potential future research would be to analyze active shooter locations to identify characteristics and see if a pattern can be extrapolated to be useful in developing risk assessment models for locations rather than individuals.

G.   SUMMARY

The literature review demonstrates that predictive analysis is a subject of great interest to American law enforcement practitioners and academics. The application of predictive analysis and the associated reductions in crime warrants that policy makers consider its application when considering solutions for specific crime problems in their jurisdictions.

It is apparent from a critical analysis of the related literature, that no cause and effect relationship between predictive analysis and the reduction of crime has been definitively established. The body of work by Braga and others has demonstrated that focusing police resources in the small geographic areas where crime concentrates can reduce crime in those areas, and even diffuse that benefit across a wider area.

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[74] Mark R. Kebbell and Louise Porter, "An Intelligence Assessment Framework for Identifying Individuals at Risk of Committing Acts of Violent Extremism against the West," *Security Journal* 25, no. 3 (2012): 212–28.

[75] Kebbell and Porter, "An Intelligence Assessment Framework for Identifying Individuals at Risk of Committing Acts of Violent Extremism against the West," 212–28.

[76] Ibid.

A significant amount of descriptive literature demonstrates that data mining, and the application of mathematical algorithms to datasets, have been used in the business world for a significant amount of time. The use of data in business informs decision makers and drives business planning for optimizing operations, predict sales, capture new markets, and a host of other applications.

In criminal justice, the use of predictive analytics is relatively new, and based on the amount of attention devoted to it in professional journals and magazines, is garnering a significant amount of interest within the community of law enforcement practitioners. A consensus seems to exist within the literature that initial experiments with predictive analysis in police departments in the United States appear to have had a positive effect on reducing crime. It is also apparent that predictive analysis takes a variety of forms, and relies on differing models and mathematical approaches to making predictions about where and when future crime will occur.

The body of work reviewed was supportive of data-driven and ILP as effective business models for police agencies to operate under. Hot spots policing appears to have been scientifically validated, and none of the studies or journal articles reviewed revealed dissenting views in this area.

What consistently emerges from the literature is, to be of value from a strategy and policy perspective, predictive analysis should be evaluated from within the framework of a specific crime problem, such as auto theft, robbery, or burglary, rather than attempting to apply it broadly across all problems simultaneously. Further, it is important to note that the analysis of data is only the first step in the successful application of predictive analysis techniques. The initial analysis must be followed with appropriate interventions, whether increased patrols, surveillance, or other law enforcement activity for the analysis to be of any benefit. A flow chart of the steps in a successful predictive analysis program might appear as in Figure 1.

Figure 1.   Flow Chart of a Successful Predictive Analysis Program

Identify Specific Crime Problem	→	Collect Data	→	Analyze Data	→	Apply Intervention(s)	→	Assess Outcome
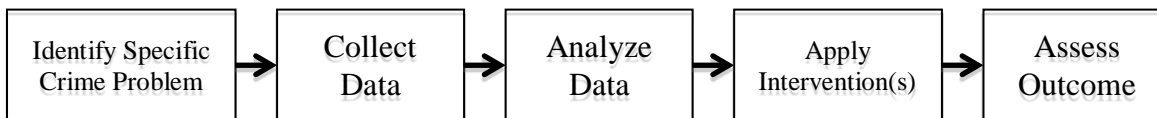
The literature revealed differing schools of thought when it comes to the ability of mathematical formulas to "predict" where and when a particular crime will occur. This difference of opinion surrounds whether the algorithms actually predict or simply provide areas of increased probability for certain crimes to occur. These differing viewpoints support the assertion in this thesis that further research into the effectiveness of predictive policing should be undertaken.

A number of gaps in knowledge were discovered during this literature review. Many of the so-called studies of predictive policing programs in U.S. police departments have been conducted by entities with parochial interests in the outcome. A majority of the literature in this area has been produced by academics who became vendors of some of the predictive policing software currently on the market. This association with a commercial interest that stands to benefit from a positive review of their product removes the appearance of objectivity from the work.

The literature has not scientifically examined predictive policing while considering other, unrelated factors that could have influenced crime at the same time as the predictive policing program was being studied.

This inquiry has not found a satisfactory amount of evidence that predictive policing has been objectively studied to the degree necessary to validate it as an effective crime reduction strategy. It is worthwhile to the field of policing and homeland security that the academic community endeavor to conduct objective, scientific studies of predictive policing so that policy makers can make evidence-based decisions in regards to what appears to be a promising addition to the arsenal of strategies that law enforcement can bring to bear when improving the resilience and security of their communities.

This thesis evaluates the effectiveness of predictive policing by conducting case studies that compare crime data to the use of predictive analysis to study the relationship between the two. The limitations of this methodology are that its scope does not include other variables that may influence an increase or decrease in crime, but it is hoped that the results will further point out the need for scientific study by qualified, objective evaluators. It is an objective of this study to add to the body of literature on the subject by consolidating the various literature and cases into a single source that may be used to make policy decisions, or influence others to conduct further studies.

III. THEORETICAL FOUNDATIONS

Predictive policing methodologies rely on the belief that humans behave in predictable ways and that future behavior can be predicted. These methodologies are rooted in a number of criminological theories that have been applied in formulating the various models and methodologies of predictive analysis. These theories are organized into three categories for discussion: repeat victimization theory, social disorganization and collective efficacy, and environmental criminology.

Repeat victimization theory states that for most crimes, the risk of victimization increases following the initial incident. This risk decreases over time, but repeat occurrences extend the time of risk. Under repeat victimization theory, previous crime targets are likely to be targeted again.[77]

Social disorganization and collective efficacy "focus on the relationship between community characteristics and problem behavior."[78] Social disorganization theory posits that economic disadvantage is one of a number of conditions that impede the development of strong social networks, community groups, and cohesive, functional neighborhoods.[79] The ability for community residents to regulate social control through organized groups and strong relationships is known as collective efficacy.[80] Neighborhoods experiencing social disorganization are known to have diminished collective efficacy.[81] Violent crime has been shown to be higher in these areas that experience a lack of social control.[82]

Rational choice theory and routine activities theory both fall under the broader area of environmental criminology. Rational choice theory presumes that offenders

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[77] Bachner, "Predictive Policing: Preventing Crime with Data and Analytics"; Farrell and Sousa, "Repeat Victimization and Hot Spots."

[78] Craig D. Uchida, "Encyclopedia of Criminology and Criminal Justice," ed. Gerben Bruinsma and David Weisburd, 2014, http://link.springer.com/10.1007/978-1-4614-5690-2.

[79] Ibid.

[80] Ibid.

[81] Ibid.

[82] Ibid.

consider certain factors and that a decision-making process exists that an offender engages in when deciding whether to commit a particular crime at a certain place and time.

The premise of routine activities theory is that for a crime to take place, a motivated offender must be present who encounters a suitable target or victim, at a place that lacks a capable guardian.[83] These three factors give police an opportunity to collect and analyze data on each of the things that must come together for a crime to occur. Data on crime locations, crime victims, and offenders provide an opportunity for collection and analysis of each individual factor. Comprehensive data collection on crime locations, crime victims, and offenders and subsequent analysis, can help discern useful information about historical crimes that can be of value in forecasting future crimes. All three factors must converge at the same place and time and are illustrated in what is known as the "crime triangle" (Figure 2).

Figure 2.   Crime Triangle

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[83] Lawrence E. Cohen and Marcus Felson, "Social Change and Crime Rate Trends: A Routine Activity Approach," *American Sociological Review* 44, no. 4 (August 1, 1979): 588–608, doi:10.2307/2094589.

Since rational choice theory assumes that offenders make a conscious decision whether to commit a crime, situational crime prevention assumes that crime can be prevented by increasing the risks associated with committing a crime through target hardening, increasing the likelihood of capture, or reducing the rewards of that crime.[84] This concept is particularly important in applying predictive analysis models because forecast models must be followed by an appropriate police intervention to be effective. If no intervention is applied based on the analysis, the environmental factors remain unchanged and the offenders do not perceive any increased risk associated with their decision making.

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[84] Groff and La Vigne, "Forecasting the Future of Predictive Crime Mapping."

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IV. PREDICTIVE POLICING MODELS/METHODOLOGIES

It is a widely held belief that crime and disorder concentrate in small clusters, or "hot spots," and that the majority of crime takes place in a small percentage of places, while most other areas are relatively crime free.[85] Studies have shown that focusing police activity in these hot spots can be effective at preventing or reducing crime.[86] Proactive interventions, such as directed patrols, or increased traffic enforcement, were associated with reduced crime in the hot areas without an apparent displacement of the crime problem to other areas. Hot spots policing is driven by the assumption that historical performance is the best indicator of future performance, and that if a particular location has been a concentrated crime location in the past, it will continue to be so in the future. Hot spot policing is dependent on historical data to drive decision making on how to deploy police resources during the present time frame, as well as in the future.[87]

Reactive policing models, in which police respond to calls for service and investigate past crimes, is not the most effective method for reducing crime. According to Telep et al., of The Center for Evidence Based Crime Policy at George Mason University, proactive policing methods are most effective at reducing violent crime.[88]

It is widely held that by focusing police attention on these crime clusters, overall crime can be reduced because the majority of crime occurs in these small clusters. Research into hot spots policing indicates that it is an effective crime control strategy.[89]

One of the shortcomings of hot spots policing is that it is dependent upon historical data of where crimes have occurred in the past, and the presumption that because crime has clustered in certain places in the past, these places will continue to

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[85] Braga and Weisburd, *Policing Problem Places.*

[86] Braga, "The Effects of Hot Spots Policing on Crime."

[87] Telep, *Police Interventions to Reduce Violent Crime: A Review of Rigorous Research.*

[88] Ibid.

[89] Anthony A. Braga, "Hot Spots Policing and Crime Prevention: A Systematic Review of Randomized Controlled Trials," *Journal of Experimental Criminology* 1, no. 3 (September 1, 2005): 317–42, doi:10.1007/s11292-005-8133-z.

experience crime. This approach does not necessarily offer predictions or forecasts of where future crime is likely to occur.

Most predictive policing methodologies fall into one of three general categories: analysis of space, analysis of time and space, and analyses designed to detect persons of interest.[90]

A variety of advanced statistical techniques is used to create predictive models. Regression analysis is a basic way to model the relationship between two variables. In policing, examples of variables examined could be the type of crime and time of day, type of incident and location, call volume and time of day, or the relationship between two crimes, such as residential burglary and vandalism. Basic regression models allow analysts to plot the locations of incidents or crimes on a map for analysis. Regression models that use multiple independent variables to predict the future value of a dependent variable (in this case, the likelihood of crime) are referred to as "multivariate" logistic regression models. According to Ferguson, multivariate models "improve forecasting effectiveness."[91] Groff points out that effectiveness "depends on the selection of the appropriate variables."[92] Regression analysis is a useful tool for identifying and mapping hotspots. While regression techniques are a common method to demonstrate the relationship between variables and plot crime hotspots, Uchida writes, "The statistical techniques used in predictive analytics are largely untested and have not been rigorously evaluated."[93]

A number of location-based predictive analysis programs depend on repeat victimization theory and mathematical processes to create near-repeat modeling to produce maps of locations where crimes are most likely to occur. These models depend on point processes models to analyze data and predict future crime. "A point process is a random collection of points falling in some space. In most applications, each point

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[90] Bachner, "Predictive Policing: Preventing Crime with Data and Analytics."

[91] Andrew Guthrie Ferguson, "Predictive Policing and Reasonable Suspicion," *Emory Law Journal* 62 (2012): 259–325.

[92] Groff and La Vigne, "Forecasting the Future of Predictive Crime Mapping."

[93] Uchida, "Encyclopedia of Criminology and Criminal Justice."

represents the time and/or location of an event, such as a lighting strike or an earthquake."[94] Individual crime occurrences can be plotted as point processes as well.

Research has been conducted that concluded that near-repeat crimes behave in a similar manner to earthquake aftershocks, and that models used to describe aftershock occurrences can also be applied in crime forecasting. These models are known as self-exciting temporal point processes, referred to by many as Hawkes processes.[95] In a self-exciting points process, each occurrence of a point (e.g., earthquake, or crime) causes other points to be more likely to occur.[96] "Whereas in a self-correcting process, the points have an inhibitory effect."[97]

Researchers at UCLA fit a self-exciting point process model to a dataset of residential burglaries that occurred in a district of the city of Los Angeles during the years 2004–2005. They found that self-exciting point processes "can be adapted for the purpose of crime modeling,"[98] and that the predictive accuracy of the process is better than hot spot mapping.[99]

This self-exciting point process was incorporated into the predictive policing programs in California, in both Santa Cruz, and Los Angeles, to forecast the locations most likely to be targeted for burglaries and thefts from autos.

Risk Terrain Modeling (RTM), a location-based model, operates under the presumption that crime does not distribute evenly. As previously stated, most terrain is crime free, while most crime concentrates in certain areas. Rather than focus on relying only on past crime data, RTM attempts to identify risk factors that indicate a propensity for crime and create a map indicating the risk value for every place within a specific

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[94] Frederic Paik Schoenberg, "Introduction to Point Processes" (Los Angeles: UCLA Department of Statistics, 2011), http://escholarship.org/uc/item/4k35g3w6.pdf.

[95] Christopher Stover, "Hawkes Process," *MathWorld--A Wolfram Web Resource*, accessed December 14, 2014, http://mathworld.wolfram.com/HawkesProcess.html.

[96] Schoenberg, "Introduction to Point Processes."

[97] Ibid.

[98] George O. Mohler et al., "Self-Exciting Point Process Modeling of Crime," *Journal of the American Statistical Association* 106, no. 493 (March 1, 2011): 100–108, doi:10.1198/jasa.2011.ap09546.

[99] Ibid.

geographic area. Risk factors are those environmental characteristics about a particular place that contribute to an increased risk of crime occurring at that location. Raster maps are created, and each cell on the map is populated with a value for each risk factor present in that cell. Once these risk factors are mapped, police executives can make resource deployment decisions to ensure that police efforts are directed to the right places at the right times.[100]

The Irvington, NJ, police department is one agency that has experimented with RTM to reduce the number of shootings in the jurisdiction.

A. DATA

In all cases, the quality of analytical output is only as good as the quality of the data being analyzed. It is more common today than in the past that police departments possess computerized records management systems, as opposed to paper records. It is estimated that the amount of data in the world will double every 20 months,[101] and with every event or incident, so too will increasing opportunities to collect and store data for later analysis increase.

What type of data is needed to conduct predictive analysis? "The most basic predictive models rely on past crime data."[102] Basic data, such as type of incident, time of occurrence, and day of the week, can be incorporated into crime maps that demonstrate when and where crimes have been committed. This information can be useful to visualize trends and identify crime hotspots, but the output is historical in nature. It indicates where crimes have occurred in the past, but does not account for the movement of crime to other places.

This research has revealed that a broader spectrum of data is being collected to generate predictions. Information about the crime location, weather, and offenders that

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[100] Joel M. Caplan and Leslie W. Kennedy, *Risk Terrain Modeling Manual: Theoretical Framework and Technical Steps of Spatial Risk Assessment for Crime Analysis* (Newark, NJ: Rutgers Center on Public Security, 2010).

[101] Colleen McCue and Andre Parker, "Connecting the Dots: Data Mining and Predictive Analytics in Law Enforcement and Intelligence Analysis," *Police Chief* 70, no. 10 (2003): 115–24.

[102] Bachner, "Predictive Policing: Preventing Crime with Data and Analytics."

tend to contribute to the occurrence of crime are included in the analysis provided to the police. Bachner categorizes these variables into three categories: spatial, temporal, and social network. Figure 3 lists examples of each category of variable.

Figure 3.   Examples of Variables Used in Predictive Policing

Spatial Variables	Temporal Variables	Social Network Variables
Indicators of Areas with Potential Victims/Targets • Shopping malls • Property values • Hotels • Area demographics • Population density • Residential instability **Indicators of Escape Routes** • Highways • Bridges • Tunnels • Public transportation • Railways • Dense foliage **Indicators of Criminal Residences** • Bars and liquor stores • Adult retail stores • Fast food restaurants • Bus stops • Public health information • Areas with physical decay	• Payday schedules • Time of day • Weekend vs. weekday • Seasonal weather (e.g., hot versus cold weather) • Weather disasters • Moon phases • Traffic patterns • Sporting and entertainment events	• Kinship • Friendship • Affiliation with an organization • Financial transaction • Offender/victim

Source: Jennifer Bachner, "Predictive Policing: Preventing Crime with Data and Analytics" (IBM Center for the Business of Government, 2013), http://www. businessofgovernment.org/report/predictive-policing-preventing-crime-data-and-analy tics.

The literature addressing data quality points out that accuracy of location data is important to predictive accuracy. In 2012, Hart and Zandbergen studied the impact of data quality on predictive crime mapping. Their research found a direct relationship between the accuracy of location data and predictive accuracy.[103] The study concluded

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[103] Timothy C. Hart and Paul A. Zandbergen, "Effects of Data Quality on Predictive Hotspot Mapping," National Criminal Justice Reference Service, 2012, https://www.ncjrs.gov/pdffiles1/ nij/grants/239861.pdf.

that "No one hotspot mapping technique is superior to any other,"[104] and that a number of factors influence predictive accuracy, such as variations in crime type, as well as the type of reference data used to geocode crime locations.[105] Notwithstanding the impact of other variables, an important finding of the research was that that the more accurate the location, the greater the accuracy of the prediction.[106]

Additionally, even if the agency has the appropriate type and quality of data, it must be in a compatible format for the analytical software to be able to use it. During the initial phases of the Santa Cruz predictive policing program, personnel initially had to extract crime data from the department's records management system and create spreadsheets every day to apply the predictive algorithm. This process is now automated by the use of predictive policing software.

B.   INTERVENTIONS

A discussion of data driven approaches to policing, such as hot spot or predictive policing, would not be complete without a discussion about the importance of the appropriate interventions required to make use of the analysis of data. Mapping hotspots and forecasting locations most likely to host future crime are of no value if they are not acted upon. Crime predictions and forecasts must be coupled with interventions designed to make best use of the data. Interventions could be as simple as directed patrols in the identified hot spots. Research by Koper has shown that if police spend as little as 15 minutes per two-hour period in a specific location, that location is less likely to experience crime.[107]

Police in Santa Cruz were directed to spend extra time in 150 x 150 meter squares on their beat that were identified as hot spots, while the LAPD used 500' by 500' squares for their directed patrols.

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[104] Hart and Zandbergen, "Effects of Data Quality on Predictive Hotspot Mapping."

[105] Ibid.

[106] Ibid.

[107] Christopher S. Koper, "Just Enough Police Presence: Reducing Crime and Disorderly Behavior by Optimizing Patrol Time in Crime Hot Spots," *Justice Quarterly* 12, no. 4 (December 1, 1995): 649–72.

Research into predictive and hot spot policing has been conducted to determine if the crime reductions experienced from hot spot policing were genuine reductions in crime, or did they result from the crime moving, or "displacing," out of the hot spot to another area. The research indicates that in most cases, crime displacement does not occur as a result of hot spots policing.[108] It is thought to be because the environmental factors that exist within the hot spots that make them vulnerable to crime, may not exist in the areas adjacent to the hot spot, and are therefore, not likely candidates for crime to be displaced to.[109] In fact, some evidence supports that a diffusion of crime reduction benefits has occurred outside of the hot spot areas.[110]

Addressing environmental factors that contribute to a location's vulnerability for crime are also appropriate and effective interventions. Using a problem solving approach that looks beyond merely arrests as a solution for crime are much more effective. Examples of correctable environmental factors are poor lighting, as well as a lack enforcement of building codes at nuisance properties.

C.   ONGOING RESEARCH

This research has found that many of the developers of the existing predictive analysis techniques currently in use have turned their algorithms into commercial products for sale to the law enforcement market. Few, if any, independent studies of their techniques have been conducted to validate the accuracy and effectiveness of predictive analysis.

The NIJ is supporting the implementation and evaluation of the impact of the predictive policing concept. NIJ has conducted two symposiums that brought together police leaders, researchers, and criminal justice practitioners to discuss the predictive analysis concept. The first symposium took place in 2009 in Los Angeles. Attendees at

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[108] Braga, "Hot Spots Policing and Crime Prevention."

[109] Ibid.

[110] Ibid.

the Los Angeles symposium attended sessions concerning impacts on policy and privacy, as well as the technical issues surrounding predictive policing.[111]

In 2009, the NIJ awarded seven police departments, NYPD, Chicago, Shreveport, Boston, Washington, DC, Los Angeles, and Maryland State Police, competitive planning grants to develop predictive policing models for their respective jurisdictions.[112] The RAND Corporation was enlisted to evaluate the seven demonstration projects and produced the report referenced earlier.

In 2011, Chicago was awarded $1.5 million, and Shreveport $516,474 for phase 2 of the demonstration and evaluation program to evaluate the strategies they developed in phase 1.[113]

The NIJ has other ongoing efforts to link predictive analysis theory to practice, including a solicitation for funding the testing of geospatial predictive policing strategies.

The results of the Chicago program has not been published as of this writing, but the evaluation of the Shreveport program has been produced and is discussed further in a later chapter. Notwithstanding the Shreveport study, this research has not uncovered any other rigorous, controlled, studies of the use of predictive analysis by police departments to reduce crime.

D.   MEASURING EFFECTIVENESS

In evaluating the effectiveness of predictive policing, this research found anecdotal evidence of a correlation between the implementation of predictive analysis techniques and crime reduction. Much of this anecdotal evidence comes from vendor advertising, magazine and news articles, and professional journals, but little in the way of peer reviewed articles or academic studies have been produced. A number of the mathematicians and other scientists that designed the most successful predictive analysis algorithms have since gone into business to market their techniques commercially to law

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[111] "Predictive Policing," accessed October 19, 2013, http://www.nij.gov/topics/law-enforcement/ strategies/predictive-policing/welcome.htm.

[112] Ibid.

[113] Ibid.

enforcement agencies. Dr. George Mohler, and Dr. Jeff Brantingham, took the techniques experimented with in Santa Cruz, and formed PredPol, one of the more successful vendors that market predictive analysis software to police agencies. PredPol has accumulated dozens of clients since its establishment in January 2012, and according to the PredPol website, the software is responsible for reducing crime in jurisdictions across the United States and the United Kingdom.[114]

While Mohler and Brantingham clearly have the expertise to conduct scientifically rigorous evaluations of predictive policing, their business interests would call into question the objectivity of any study conducted.

This research project has not found the existence of a uniform, objective measurement of what constitutes an effective, or accurate predictive analysis technique. The scientific and academic community has not produced a standard metric by which to measure.

In Santa Cruz, well before rolling out predictive policing department-wide, the police department tested the algorithms developed by Mohler by measuring the frequency with which crime occurred within the 500 by 500 foot predictive policing boxes when the software predicted one would occur. While a department representative relayed that the formula was approximately 30% accurate when tested against itself,[115] without any other variables, such as police intervention being changed, no hard data were available to document this estimate.

In Atlanta, where the Atlanta Police Department is also a PredPol client, the PredPol team established a Predictive Accuracy Index (PAI) score to represent the number of crimes accurately predicted within the zones experimenting with predictive analysis deployment. A PAI of 1 represents random chance, and values over 1 represent increasing accuracy of prediction. Over a 90-day period, two of the city's six zones experimented with predictive policing, and the PAI values for the two zones were 23.7 and 24.0, respectively. While PAI appears to be an objective measurement of accuracy,

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[114] "Predict Crime," accessed September 13, 2015, https://www.predpol.com/.

[115] Deputy Chief Steven Clark, personal communication, January 12, 2015.

and the PAI in the two predictive policing zones was better than 20%, the Predictive Accuracy Index and the evaluation of PredPol's effectiveness was performed by PredPol itself, thereby, negating its objectivity from an academic point of view.

Part 1 crime data is publicly available for those police departments that report such data. Although Part 1 crimes are self-reported by the agencies themselves, Part 1 crime data is the generally accepted method for measuring and comparing crime rates in the United States.

To measure the effectiveness of predictive policing, or any other crime reduction program for that matter, the pertinent data for the crime reduction program must be available to analyze the relationship between the program and crime. In predictive policing, the analysis of data to make predictions is only the first step in a two-step process. Some type of police intervention in the field to address the predicted crime must accompany such predictions. A prediction without an accompanying intervention may very well have value in creating forecasts, but will have no impact on crime itself.

To evaluate the effectiveness of police interventions within predictive policing hotspots, data regarding the frequency (how often), and dosage (how much) needs to be collected and compared to the crime data to determine the relationship between the two. In Santa Cruz, officers in the field were required to document how often, and for how long, they patrolled within the predictive policing boxes, and department managers were able to track and analyze this data through the department's computer-aided dispatch (CAD) system. Unfortunately, this frequency and dosage data was not available for study.

Even with a complete dataset of crime data, predictions, and interventions with which to analyze the effectiveness of a predictive policing program, it is not known what other variables may have had an impact on crime at the same time the predictive policing was happening.

The following chapters focus on the predictive policing programs of three agencies and analyze the relationship between each program and quantitative crime data for the associated jurisdiction.

V. CASE STUDY—SANTA CRUZ, CALIFORNIA

The city of Santa Cruz is located on the California's central coast on the northern edge of Monterey Bay, encompassing a total of 15.828 square miles.[116] Its estimated 2013 population was 62,864,[117] but during the summer months, senior police officials estimate that beachgoers and vacationers nearly double that figure.[118] The city is also home to the University of California, Santa Cruz, which enrolled 16,543 students for the 2013–2014 academic year.[119]

The Santa Cruz Police Department consists of 94 sworn personnel and responds to over 90,000 calls for service annually. The department reported 3,819 Part I crimes during calendar year 2014.[120] Over a period of years, the department experienced increasing demands for service without a commensurate increase in personnel. Annual calls for service increased from 72,601 in 2007, to 90,484 in 2011. Annual Part 1 crimes increased from 2,946 to 3,849 for the same time period.

Part 1 crimes consist of the following "index crimes:" homicide, forcible rape, robbery, aggravated assault, burglary, larceny (theft), auto theft, and arson. The Santa Cruz Police Department collects and reports Part 1 crime data as part of the Uniform Crime Reports (UCR) program, a "nationwide, cooperative statistical effort of nearly 18,000 city, university and college, county, state, tribal, and federal law enforcement agencies voluntarily reporting data on crimes brought to their attention."[121] The UCR

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[116] "2010 Census Gazetteer File-Places-California," accessed January 12, 2014, http://www.census.gov/geo/maps-data/data/docs/gazetteer/2010_place_list_06.txt.

[117] "American FactFinder—Results," accessed January 13, 2015, http://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk.

[118] Deputy Chief Steven Clark, in discussion with the author, January 12, 2015.

[119] "UC Santa Cruz Facts," accessed January 27, 2015, http://admissions.ucsc.edu/apply/parents-and-guardians/prospective-students/facts.html.

[120] "Department Structure and Facts," accessed January 13, 2015, http://www.cityofsantacruz.com/departments/police/about-us/department-facts.

[121] "Summary of the Uniform Crime Reporting Program," 2010, https://www.fbi.gov/about-us/cjis/ucr/leoka/leoka-2010/aboutucrmain.

program provides a standard collection and reporting mechanism to compare crime statistics nationwide.

Seeking a solution to increasing demand for service and increasing crime, the Santa Cruz Police Department (SCPD) approached Santa Clara University researcher George Mohler in 2010. Mohler at that time was working on computational methods to predict crime hotspots using self-exciting point processes originally developed for predicting earthquake aftershocks. The SCPD agreed to provide their crime data to Mohler as part of the experiment.

Initially, Deputy Chief Steven Clark, and Analyst Zach Friend, had to extract data from their records management system and create spreadsheets every day so that new analysis could be done every night to identify predictive hot spots for the following day. From January 2001 to July 2011, Mohler's algorithm was tested against itself to determine the level of accuracy of predicting the locations of future crime. This experiment was performed without applying any interventions into the forecast areas, or informing department personnel about what they were doing. Their intention was to evaluate the algorithm without officers changing their behavior or introducing any other variables, such as added patrols, into the experiment.[122]

The experiment focused on three crime types: burglary, burglary from auto, and auto theft. In 2013, this list was expanded to include deadly weapon assault, battery, and gang activity. Their findings were that the algorithm was generally around 30% accurate at forecasting where and when a certain crime type would occur. Occasionally, 60% accuracy was experienced.[123]

By July 2011, Clark and Friend were confident enough in the algorithm to do a soft rollout to the department. Officers were directed to spend a portion of their unobligated time in the hot spot boxes within their beats. The department experimented with the number of boxes that would be identified each day, starting initially with 10, then 20, which was found to dilute the accuracy of the predictions. The department

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[122] Clark, in discussion with the author.

[123] Ibid.

ultimately settled on generating 15 predictive policing boxes per day. The department's CAD was used to document how often and for how long, or the "frequency" and "dosage," police officers spend time within the boxes.

Today, the SCPD uses the commercial version of the software that Mohler helped develop to extract crime data automatically from the SCPD records management system and creates predictive crime maps within two hours before the start of each of the department's three patrol shifts. Paper copies of the maps are distributed to patrol officers at roll call and are available to supervisors and administrators electronically via an Internet connection. The current version of the software interface can be adjusted by the user to display maps for all six crime types or any combination of the six, and can overlay past crimes over user defined periods, as well as review previous predictive policing maps.

The anecdotal findings per the SCPD are that its predictive policing program was more effective than hot spot policing, and that its effectiveness is dependent on the amount of intervention applied in the predictive policing boxes. When analyzing crime data, the results of predictive policing on crime were not so clear.
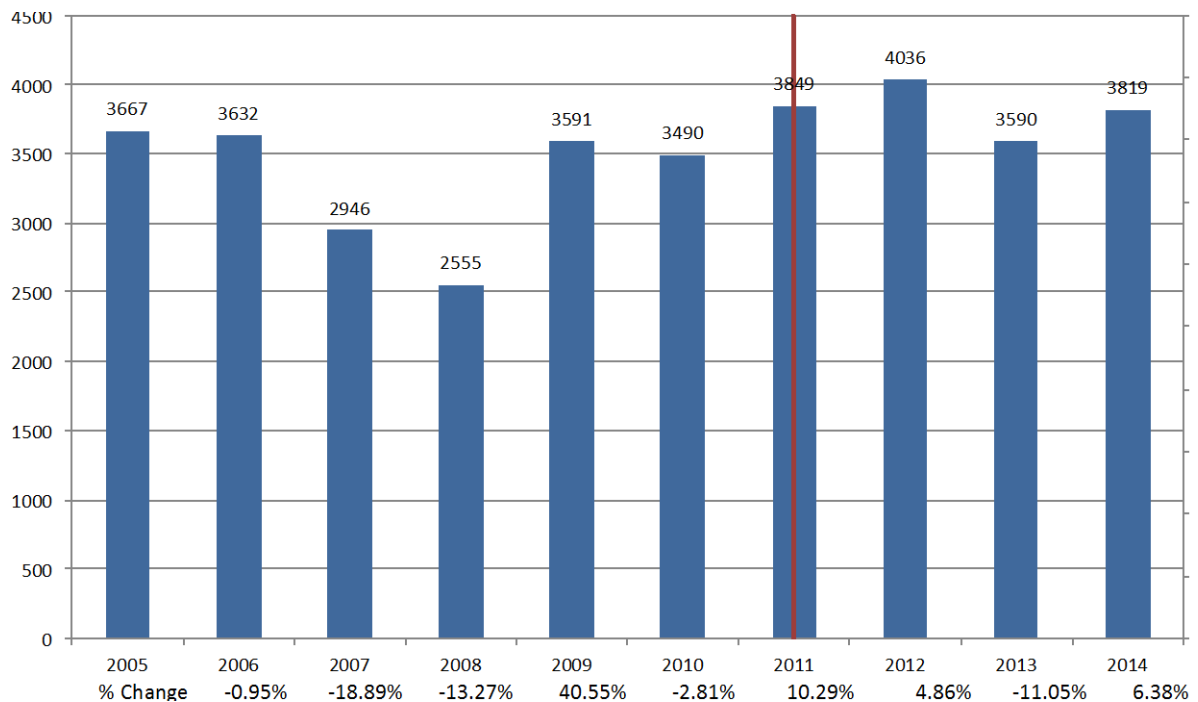
Publicly available crime data for Santa Cruz was analyzed to evaluate the relationship between the predictive analysis program and its effects on crime. Since the initial focus crimes were burglary, thefts from autos, and auto theft, data on those crimes was extracted from the SCPD's monthly and annual published crime statistics. Crime data was available for the calendar years 2005–2014.

The SCPD rolled out its predictive policing program in July 2011, so the data on the three focused crimes were evaluated to determine if a reduction or increase in those crimes occurred following the introduction of predictive policing. The data regarding the type, frequency, and dosage of police intervention were not available for this research.

Overall Part 1 crimes during the 2005–2014 period fluctuated between a low of 2,555 in 2008, and a high of 4,036; the first full year after predictive policing was implemented. Of the three focus crimes, only burglary was consistently down in each year following implementation as compared to 2011. Auto theft numbers were greater

than the 2011 total in each year following implementation; reaching its highest amount, 264, in 2012. This number is the highest of the entire 2005–2014 time period. In the theft from auto category, 2012 and 2014 saw a greater volume of that offense than 2011. Only 2013's total was lower than 2011 (Figures 4–7, red vertical line indicates rollout of predictive policing program).
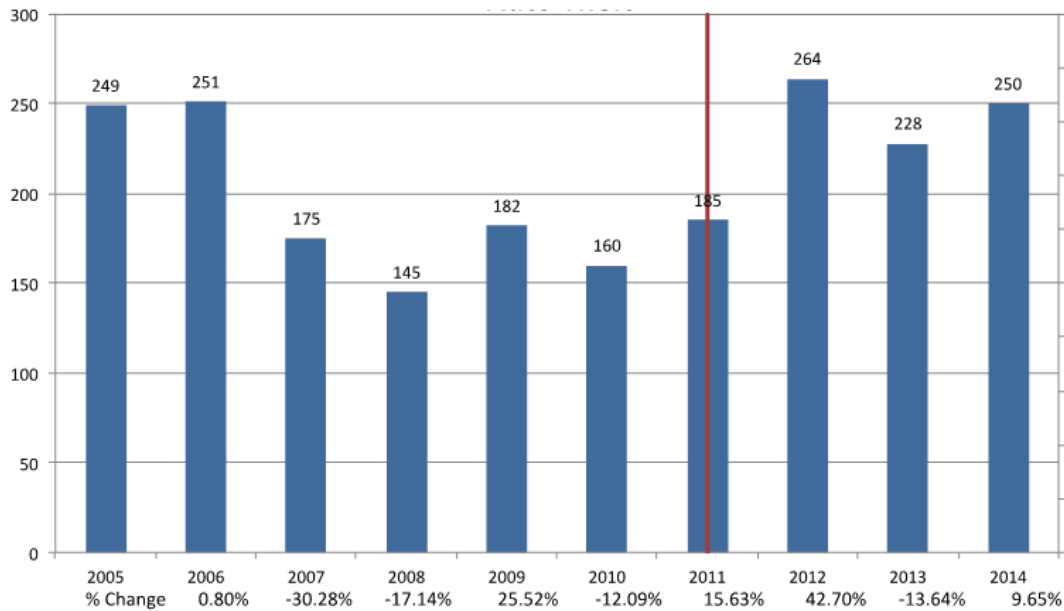
Figure 4.   Santa Cruz Data 2005–2014 Part 1 Crimes

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	3667	3632	2946	2555	3591	3490	3849	4036	3590	3819
% Change		-0.95%	-18.89%	-13.27%	40.55%	-2.81%	10.29%	4.86%	-11.05%	6.38%

Source: "Annual Statistics," accessed January 13, 2015, http://www.cityofsantacruz.com/ departments/police/crime-statistics/annual-statistics.

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Figure 5.   Santa Cruz Crime Data 2005–2014 Auto Theft

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	249	251	175	145	182	160	185	264	228	250
% Change		0.80%	-30.28%	-17.14%	25.52%	-12.09%	15.63%	42.70%	-13.64%	9.65%

Source: "Annual Statistics," accessed January 13, 2015, http://www.cityofsantacruz.com/ departments/police/crime-statistics/annual-statistics.
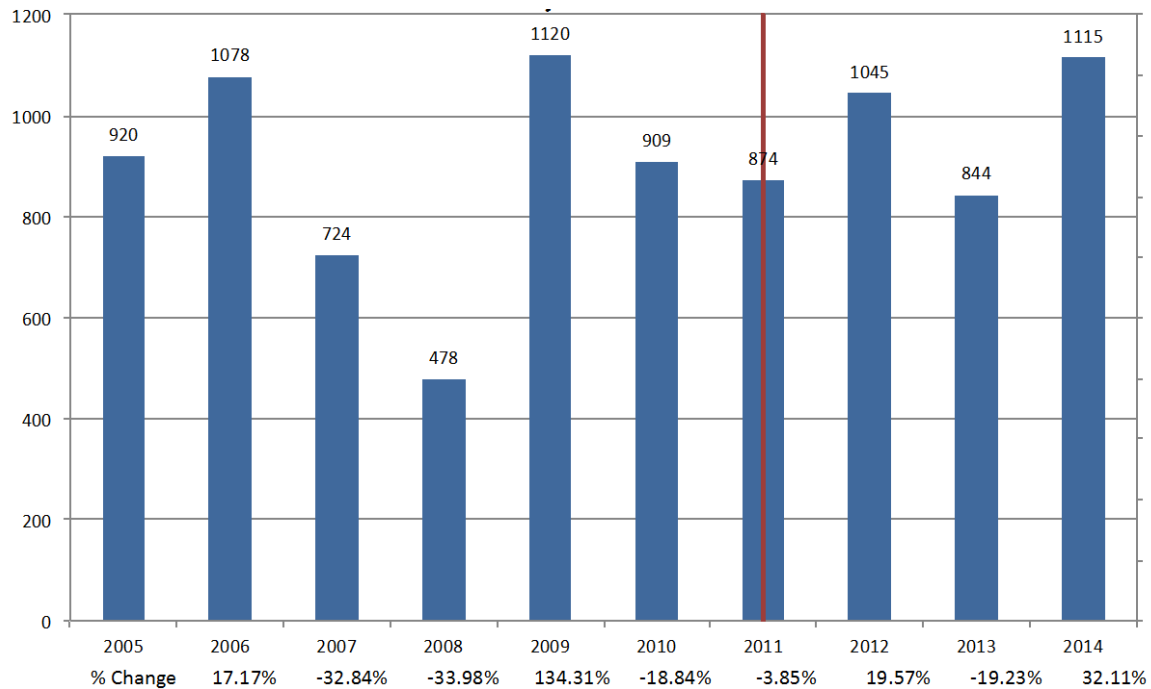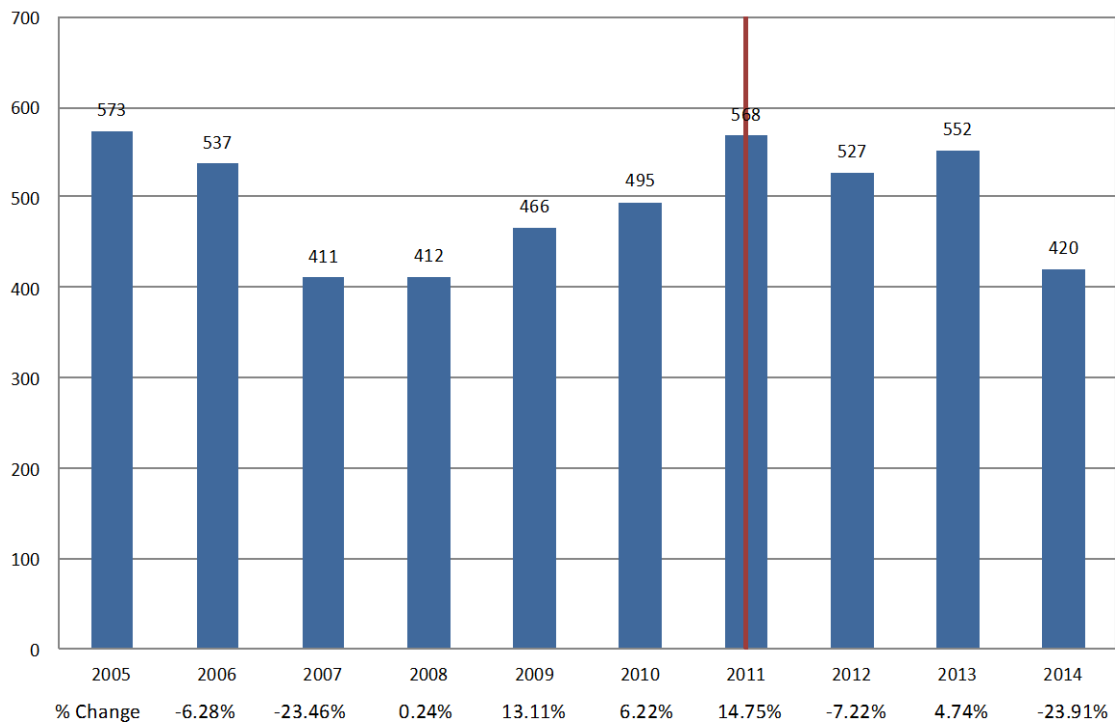
Figure 6.   Santa Cruz Crime Data 2005–2014 Larceny from Vehicle

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	920	1078	724	478	1120	909	874	1045	844	1115
% Change		17.17%	-32.84%	-33.98%	134.31%	-18.84%	-3.85%	19.57%	-19.23%	32.11%

Source: "Annual Statistics," accessed January 13, 2015, http://www.cityofsantacruz.com/ departments/police/crime-statistics/annual-statistics.

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Figure 7.   Santa Cruz Crime Data 2005–2014 Burglary

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	573	537	411	412	466	495	568	527	552	420
% Change		-6.28%	-23.46%	0.24%	13.11%	6.22%	14.75%	-7.22%	4.74%	-23.91%

Source: "Annual Statistics," accessed January 13, 2015, http://www.cityofsantacruz.com/
departments/police/crime-statistics/annual-statistics.

This research does not consider other factors at work that may have had an impact on crime during the same time period. It is difficult to judge the impact of predictive policing based solely on the available crime data, as this initiative did not occur within a vacuum.

At approximately the same time that Santa Cruz was implementing its predictive policing program, the state of California implemented a sweeping prison realignment program that resulted in the shifting of responsibility for thousands of convicted offenders from the state prison system to county jails.

In May 2011, in response to overcrowding and unconstitutionally poor medical and mental healthcare, the U.S. Supreme Court upheld a lower court ruling that

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California must "reduce its prison population to 137.5% of design capacity"[124] before June 2013.[125] On October 1, 2011, a mere three months after the Santa Cruz predictive policing rollout, legislation supported by Governor Brown to shift responsibilities for incarceration of certain felons from the state prison system to the counties went into effect.[126] This shifting of responsibility had a cascading effect, causing overcrowding in local jails and forcing early releases of thousands of inmates to relieve the overcrowding. It is estimated that every month, approximately 13,500 inmates are released early from county jails.[127]

It is unknown for certain what effect the realignment plan has had on crime or what the future impacts will be. According to the California Attorney General's Office, crime dropped statewide in every offense category between 2009 and 2010.[128] Mixed opinions have been voiced on how prison realignment has impacted crime since its 2011 implementation. A study by The Center of Juvenile and Criminal Justice claimed that there are "no conclusive trends demonstrating a causal relationship between Realignment and crime."[129] Nonetheless, certain crime categories in certain locations have experienced increases, as illustrated by the Santa Cruz data. As with predictive policing, not enough time has passed, nor has a definitive link been established between realignment and crime.

The California Public Safety Realignment program is an illustration of factors that could affect crime concurrently with predictive policing. These factors are mostly unknown, and/or the data were not available for study. This analysis of Santa Cruz's

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[124] California Department of Corrections and Rehabilitation, *Fact Sheet: Three-Judge Panel and California Inmate Population Reduction* (San Pablo, CA: California Department of Corrections and Rehabilitation, 2011).

[125] Ibid.

[126] "Public Safety Realignment," accessed January 27, 2015, http://www.cdcr.ca.gov/realignment/.

[127] Paige St. John, "Early Jail Releases Have Surged since California's Prison Realignment," *Los Angeles Times*, August 16, 2014, http://www.latimes.com/local/crime/la-me-ff-early-release-20140817-story.html#page=1.

[128] Kamala D. Harris, *Crime in California 2010* (Sacramento, CA: Office of the Attorney General, California Department of Justice, 2011).

[129] Mike Males and Brian Goldstein, *California's 58 Crime Rates: Realignment and Crime in 2012* (San Francisco, CA: Center on Juvenile and Criminal Justice, 2014).

predictive policing program was not isolated from the other factors that could have had an impact at the same time.

Call for service data was unavailable for 2012, 2013, and 2014. While this research did not determine that a noteworthy reduction in crime had occurred following the implementation of predictive policing in Santa Cruz, knowing predictive policing's impact on call volume would be useful, as a significant reduction in call volume could enable the department to refocus resources on other operational tasks.

VI. CASE STUDY—ATLANTA, GEORGIA

The city of Atlanta is the capital of Georgia and is also the state's most populous city.[130] Serving an estimated 447,841 residents, and an area of 1332.4 square miles, the Atlanta Police Department has an authorized strength of 2,000 sworn officers.[131] Atlanta lies within a large metropolitan area with over 5 million residents, and has one of the largest economies in the world.[132] Atlanta is home to the third largest concentration of Fortune 500 companies and is the headquarters of well-known corporations, such as Coca-Cola, The Home Depot, and Delta Airlines. Hartsfield-Jackson Atlanta International Airport is the worlds busiest in terms of the number of passengers.[133] Atlanta is also a major media hub with networks, such as CNN, Turner Broadcasting, and The Weather Channel headquartered there.[134]

The Atlanta Police Department responded to 364,947 calls for service in 2013[135] and experienced 33,045 Part 1 crimes citywide during the same year.[136] The department sought to enhance its existing hot spot mapping with a predictive policing program, and developed an experimental program in two of the city's six patrol zones for a 90-day trial beginning in July 2013.[137] The department partnered with the developers of the algorithm

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[130] "Atlanta (city) QuickFacts from the U.S. Census Bureau," accessed February 16, 2015, http://quickfacts.census.gov/qfd/states/13/1304000.html.

[131] Atlanta Police Department, *Atlanta Police Department 2010–2014, An Overview* (Atlanta, GA: Atlanta Police Department, n.d.).

[132] "GaWC—The World According to GaWC 2012," accessed September 7, 2015, http://www.lboro.ac.uk/gawc/world2012t.html.

[133] "ACI World Releases Preliminary World Airport Traffic and Rankings for 2014—DXB Becomes Busiest Airport for International Passenger Traffic," accessed September 7, 2015, http://www.aci.aero/News/Releases/Most-Recent/2015/03/26/ACI--World-releases-preliminary-world-airport-traffic-and-rankings-for-2014--DXB-becomes-busiest-airport-for-international-passenger-traffic-.

[134] "Fortune 500 and Fortune 1000 Headquarters in Atlanta," accessed September 7, 2015, http://www.metroatlantachamber.com/business/data/fortune-500-1000-hq.

[135] "FOR Atlanta—City Performance Metrics," accessed February 16, 2015, http://foratlanta.github.io/charts/atlanta-police-department.html.

[136] Atlanta Police Department, *Atlanta Police Department 2010–2014, An Overview.*

[137] George Turner, Jeff Brantingham, and George Mohler, "Predictive Policing in Action in Atlanta, Georgia," *The Police Chief*, May 5, 2014, http://www.policechiefmagazine.org/magazine/index.cfm?fuseaction=display&issue_id=52014&category_ID=4.

used in the Santa Cruz predictive policing model, only under the umbrella of their corporation, PredPol. The mathematics is closely related to those used to study earthquakes and their aftershocks, as in Santa Cruz.[138] The Atlanta model relied on the analysis of type of crime, place of crime, and time of day to develop predictions within the same 500 by 500 foot boxes of the type used in Santa Cruz.[139]

In Zone 4, one of the experimental districts, the specific crime problems being addressed varied by shift, unlike in Santa Cruz. During the day shift, the program focused on burglary and robbery.[140] During the evening shift, vehicle crime and robbery were the focus crimes, and the overnight, or morning shift focused on vehicle crime only.[141] Twenty-one hot spots were developed for each shift within the 31-square mile district.[142]

In the 15-square mile Zone 6, located on the east side of the city, 18 hotspots were developed during each shift.[143] During the day and evening shift, burglary and vehicle crime were the focus, and the morning shift focused on all Part 1 crimes during the first 45 days of the experiment, and then the focus was narrowed to only robbery as the crime problem being addressed.[144]

According to Turner et al., overall crime in Zones 4 and 6 declined by 8 and 9 percent, respectively during the predictive policing period when compared with the preceding 90-day period.[145] During the same time period, aggregate crime rose between 1 and 8 percent in three of the other districts that were not using predictive policing, and crime in the remaining one district remained flat.[146] The 90-day experiment is described by Turner et al. in terms of addressing specific crime problems within the two zones, but

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[138] Turner, Brantingham, and Mohler, "Predictive Policing in Action in Atlanta, Georgia."

[139] Ibid.

[140] Ibid.

[141] Ibid.

[142] Ibid.

[143] Ibid.

[144] Ibid.

[145] Ibid.

[146] "PredPol Atlanta Crime Rate Reduced 19%," accessed February 16, 2015, http://www.predpol.com/predpol-atlanta/.

the results are described in terms of overall crime.[147] Results describing the outcome in terms of the specific crimes, i.e., burglary, vehicle crime, were not given. The specific interventions applied in each zone on the various shifts were also not described in the available literature.

The available literature describes the trial period as beginning in July 2013, but a specific start date was not mentioned. The Atlanta Police Department compiles and publishes its crime data on a weekly basis from Sunday to Saturday.[148] This method does not necessarily allow the first day of a particular month to align with the first day of the reporting period. To analyze the trial program for a 90-day period capturing July 2013, this analysis used Sunday June 30 as the start date due to the limitations of the reporting format and to capture the entire month of July. Additionally, since the crime data is reported in seven-day periods, it was necessary to analyze 13 seven-day periods, for a total of 91 days of data rather than the 90 days of the trial. Due to the ambiguity in the start and end date, and limitations due to the format of the data, it is expected that some discrepancy may have occurred between the results that have been reported in the press and this analysis. It is also important to note that details regarding what interventions (treatment and dosage) were applied in the prediction "boxes" were unavailable for analysis.

Atlanta Police Department crime data is publicly available via the department's website. The available data dates back to the 2009 calendar year.

In addition to comparing the crime data for the period that predictive policing was tried with the previous 90-day period, this thesis contains an analysis of the same 90-day period of the previous year. Comparing the data to only the previous 90 days does not account for seasonal differences, which may or may not have had an impact on crime.

A further limitation to this analysis is that only publicly available data was accessible for analysis. Neither the Atlanta Police Department nor its predictive software vendor, Pred Pol, has published data specific to the predictive policing program.

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[147] Turner, Brantingham, and Mohler, "Predictive Policing in Action in Atlanta, Georgia."

[148] "Atlanta Police Department," February 9, 2015, www.atlantapd.org.

For this research, crime data for each experimental district were collected. Data for the targeted crimes were evaluated to see what, if any, change occurred during the experimental period. These data were compared to targeted crimes during the 90-day period preceding the experiment, as well as the same 90-day period for the prior year. Overall Part 1 crime in the experimental districts was studied in the same manner.

These data were compared to the same targeted crimes and Part 1 crimes in the non-experimental districts in Atlanta to determine if a notable difference in crime occurred in the areas not applying predictive analysis.

This research found that in District 4, during the experimental period, the targeted crimes of robbery, burglary, theft from autos, and auto theft were 0.4 percent higher compared with the previous 90 days and seven percent higher when compared to the same period during the previous year.

In district 6, the data were similar. Targeted crimes (robbery, burglary, theft from auto, and auto theft) showed an increase of 0.8 percent over the previous 90 days and an increase of seven percent over the same period of the prior year.

In the rest of the city outside of Districts 4 and 6, the targeted crimes increased by seven percent over the previous 90 days, but decreased by 4 percent compared to the same time period the year before.

During the experimental period, this research indicated that Part 1 crime fell 2.4 percent in District 4, 4.7 percent in District 6, but rose six percent in the rest of the city as compared to the preceding 90-day period.

This analysis did not reveal a direct causal relationship, or a consistent trend between the Atlanta predictive policing experiment and crime rates. In the experimental districts, the targeted property crime rate increased over the previous 90 days, but at a lower rate than the rest of the city. As compared to the previous year, property crime rose in the experimental districts, while it went down in the rest of the city. During the same time periods, Part 1 crime went down in the experimental districts, but went up in the rest of the city.

Crime statistics published by the Atlanta Police Department demonstrate that overall crime was declining even before the implementation of predictive policing in 2013. The annual total of Part 1 offenses has gone down every year since 2009.[149] Part 1 offenses in 2009 totaled 40,708 and totaled 33,045 for 2013, an overall 18.82 percent reduction.[150] Preliminary data as of this writing for 2014 indicates that the 2014 total offenses committed will be less than 2013.[151] While it is possible that Atlanta's predictive policing program could have been a factor in continuing the downward crime trend in the city, nothing is readily apparent in the data that demonstrates a causal relationship between the two. As in the case of Santa Cruz, other factors may have contributed to Atlanta's trend, and it clearly could not have been solely due to predictive policing since Atlanta's crime trend predated predictive policing by a number of years. See Figures 8–10.

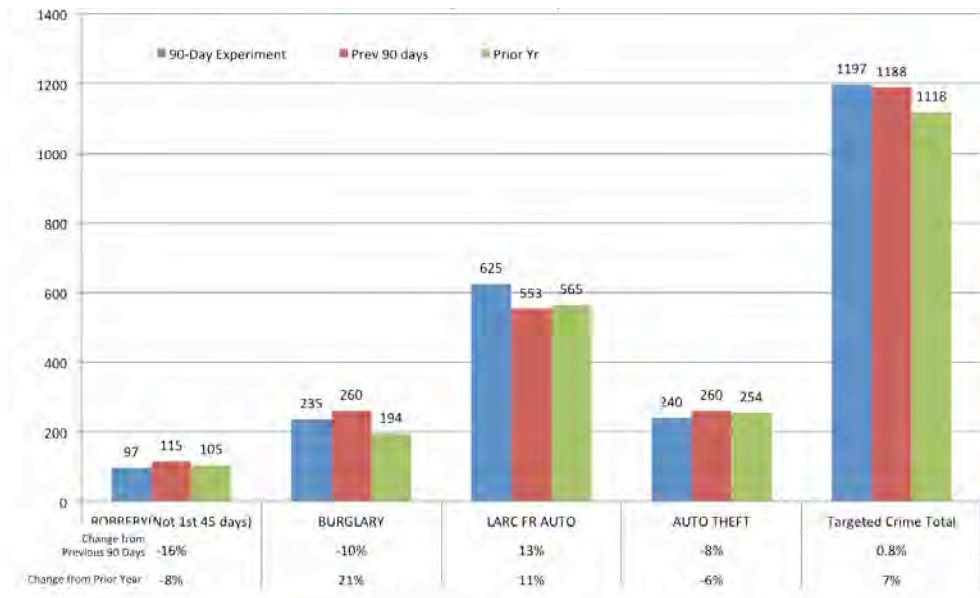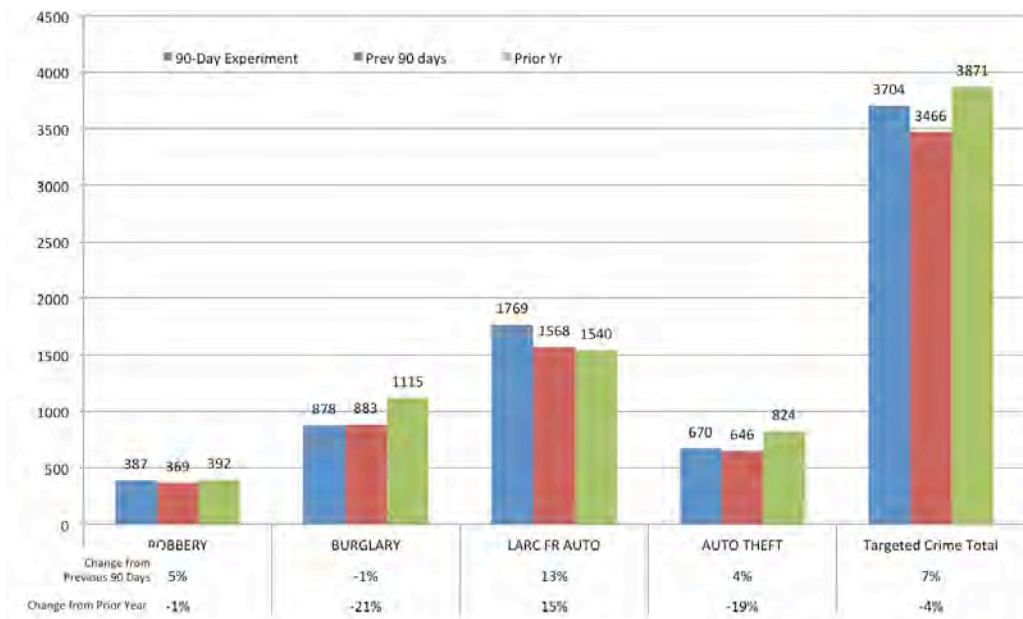Figure 8.   Atlanta Data 2014—District 4 Comparison by Crime

Source: Atlanta Police Department, "Atlanta Police Department-Crime Data Downloads," accessed February 21, 2015, http://www.atlantapd.org/crimedatadown loads.aspx.

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[149] "Atlanta Police Department."

[150] Atlanta Police Department, *Atlanta Police Department 2010–2014, An Overview.*

[151] "Atlanta Police Department."

Figure 9.   Atlanta Data 2014—District 6 Comparison by Crime

Figure 10.   Atlanta Data 2014—Rest of City (Excludes Dist 4 and 6) Comparison by Crime

VII. CASE STUDY—SHREVEPORT, LOUISIANA

Shreveport is located in the northwest corner of Louisiana and is the third largest city in the state with an estimated 2014 population of 198,242.[152] Shreveport is located adjacent to the Red River, encompassing a land area of 105.38 square miles.[153] Shreveport has benefitted from Louisiana's growing film industry with a number of feature films having been shot within the city. The greater Shreveport-Bossier City metropolitan area, with an estimated population of 446,471,[154] is also home to a growing casino industry, and the area's largest employer is nearby Barksdale Air Force Base.[155]

The Shreveport police department consists of 581 sworn officers and the agency responded to over 278,000 calls for service in 2014.[156] Total Part 1 crimes for 2014 totaled 10,728, the lowest since 1976, and also the low point in a steadily progressing downward trend since the mid-1990s[157]; see Figure 11.


[152] "American FactFinder," accessed February 21, 2015, http://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml.

[153] Ibid.

[154] Ibid.

[155] "Shreveport, LA—Official Website," accessed September 7, 2015, https://www.shreveportla.gov/Archive.aspx?AMID=42.

[156] Shreveport Police Department, *Shreveport Police Department 2014 Annual Crime Report* (Shreveport, LA: Shreveport Police Department, 2014).

[157] Shreveport Police Department, *Shreveport Police Department 2014 Crime Statistics* (Shreveport, LA: Shreveport Police Department, 2015).

Figure 11.   Shreveport, LA Part 1 Crimes
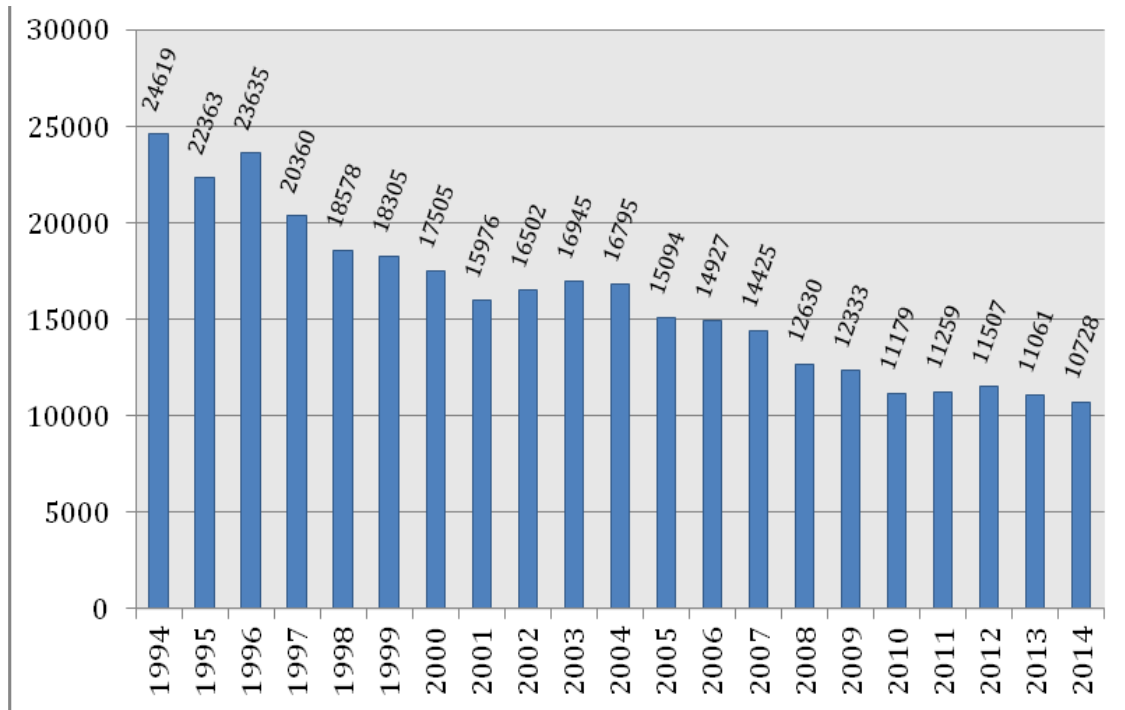
Source: Shreveport Police Department, *Shreveport Police Department 2014 Annual Crime Report* (Shreveport, LA: Shreveport Police Department, 2014).

In fiscal year 2009, the department was one of seven agencies awarded grants under phase 1 of the NIJ's Predictive Policing Demonstration and Evaluation Program.[158] In the first phase, agencies were to develop plans to implement a predictive policing program within their jurisdiction. In addition to the Shreveport Police Department, the phase 1 agencies were the New York Police Department, Boston Police Department, District of Columbia Metro Police Department, Maryland State Police, Los Angeles Police Department, and the Chicago Police Department.[159] Of the original seven agencies that participated in phase 1, in 2011 Shreveport and Chicago were selected to continue to phase 2 of the program, which entailed implementing their plans from phase 1 in the field

[158] National Institute of Justice, "Predictive Policing."

[159] Ibid.

and studying the results.[160] The Shreveport phase 2 experiment was conducted for a 7-month period from June 4, 2012 through December 21, 2012.[161]

The RAND Corporation was selected to serve as independent evaluator for phase 2, and published its report on the Shreveport predictive policing experiment in late 2014. According to RAND, the report is the "first published randomized controlled trial (RCT) of predictive policing."[162] The results of the Shreveport trial provide valuable insight for police leaders considering the development of a predictive policing program for their jurisdiction, and is the most recent scientific study of predictive policing available as of this writing.

The Shreveport Police Department divides the city into 13 geographic districts.[163] Based on budget, logistics, and crime-volume, three districts were selected for the experiment, and three were selected as control districts.[164] Dubbed, "PILOT" or Predictive Intelligence Led Operational Targeting, the approach to the Shreveport predictive policing model consisted of two components, (1) to generate predictions in the experimental districts by using multivariate regression modeling to identify small geographic locations, or hot spot "cells" of 400 feet per side in which property crimes were predicted to occur, and (2) implementing policing interventions in the predicted hotspots in an effort to prevent the predicted crimes from occurring.[165] Property crimes were defined as residential and commercial burglary, residential and business theft, thefts from vehicles, and auto theft.[166] In the control districts, police continued to use the existing practice of mapping recent crimes and providing the maps to the patrol force. To address crime hot spots, the control districts, as well as the districts in the remainder of

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[160] National Institute of Justice, "Predictive Policing."

[161] Priscilla Hunt, Jessica Saunders, and John S. Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment* (Santa Monica, CA: RAND Corporation, 2014), http://www.rand.org/pubs/research_reports/RR531.html.

[162] Ibid.

[163] Shreveport Police Department, *Shreveport Police Department 2014 Annual Crime Report*.

[164] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

[165] Ibid.

[166] Ibid.

the city, had the ability to use overtime to hire extra officers and to call in the citywide crime response unit (CRU) to provide surge personnel to address specific crime problems or special events.[167]

In the experimental districts, the NIJ grant funded overtime to conduct interventions within the predicted hot spots.[168] Two of the experimental districts, 7 and 8, fell under the same command, while the third experimental district, 11, reported to a different command.[169] The initial design of the experiment called for monthly meetings at the department and district level to "develop strategies and resource allocations to address the predicted hot spots."[170] These meetings however, did not occur as planned, leaving preventative strategies to the discretion of the respective district commanders, which resulted in different interventions being applied in the different districts.[171]

As a result of the lack of uniformity in implementation of preventative measures, the two commands applied different treatments in their respective areas.[172] Districts 7 and 8 fell under the same command, and therefore, implemented the prevention component of PILOT in the same manner.[173] The command deployed two two-officer patrol cars dedicated to PILOT operations without having to respond to routine calls for service.[174] A supervisor was also assigned and dedicated to the program.[175] As described in the Rand report, the efforts in this command focused on reducing crimes by emphasizing intelligence gathering and quality, not quantity, of arrests.[176] PILOT officers stopped people for low-level violations and ran their names against databases to

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[167] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.
[168] Ibid.
[169] Ibid.
[170] Ibid.
[171] Ibid.
[172] Ibid.
[173] Ibid.
[174] Ibid.
[175] Ibid.
[176] Ibid.

ascertain if these individuals had any active warrants, or prior convictions.[177] Officers would arrest the violators if those inquiries revealed "significant prior convictions."[178] If it was determined that the violators were on probation or parole, officers would contact their probation or parole officers, and request those officers that supervised individuals considered to be "not in good standing" come to the scene.[179] If none of the above applied, the officers would issue a warning and attempt to build a rapport with the individuals with the goal of developing actionable intelligence to reduce property crime.[180] PILOT officers also made numerous contacts with community members to develop intelligence and leads to follow up on or pass on to detectives.[181]

District 11, which fell under a separate command from Districts 7 and 8, implemented PILOT activities differently. District 11's command deployed two one-officer cars, rather than two-officer cars, and did not have a supervisor specifically dedicated to PILOT, although one was available if needed.[182] PILOT officers in District 11 were also expected to handle routine calls for service.[183] According to Rand, the District 11 strategy was less focused than Districts 7 and 8.[184] When not responding to calls for service, District 11 PILOT officers patrolled predictive cells and stopped suspicious people with a focus on narcotics offenses and truancy in an effort to reduce burglaries.[185]

In the control districts, crime analysts provided crime bulletins and maps of recent crimes to patrol officers.[186] Officers would conduct directed patrols in these areas when possible, and had the ability to call in the citywide CRU to provide surge personnel to

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[177] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

[178] Ibid.

[179] Ibid.

[180] Ibid.

[181] Ibid.

[182] Ibid.

[183] Ibid.

[184] Ibid.

[185] Ibid.

[186] Ibid.

address specific crime problems or special events.[187] It was the normal practice for the department, even outside of the experimental and control districts.[188]

For the experimental districts, the predictive algorithm was run monthly, as it was determined that the predictive hot spots did not vary much over a shorter period.[189] Maps were provided for each district, and later in the experiment, data regarding recent crimes, arrests, and other factors were overlaid on the maps and distributed to officers on a daily basis.[190]

The dosage of interventions was measured in terms of overtime, and a total of 5,233 hours of overtime, was expended to conduct preventative activities within the experimental districts.[191]

The RAND study concluded that there was "no statistical evidence that crime was reduced more in the experimental districts than in the control districts."[192] Three possible reasons were cited for this outcome. Low statistical power was cited as the first possible factor.[193] Using only three experimental, three control districts, and low monthly and district crime counts may not have captured a sufficient quantity of data to obtain meaningful results.[194]

Program implementation failure was also cited as a possible reason. Disparate treatment in the experimental districts, with varying levels of effort during the seven-month trial, was not in conformance with the original proposed model for the trial.[195] During the first four months of the trial, property crime in Districts 7 and 8, both of which fell under the same command, experienced a 35 percent drop in comparison to the

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[187] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

[188] Ibid.

[189] Ibid.

[190] Ibid.

[191] Ibid.

[192] Ibid.

[193] Ibid.

[194] Ibid.

[195] Ibid.

control districts.[196] During the final three months of the experiment, a small increase in crime as compared to the control districts was observed.[197] The Rand researchers could not draw a definite conclusion to explain the drop in crime during the first four months other than an observed decrease in man-hours was devoted to the PILOT program during the last three months of the experiment.[198] This decline was due to a reduction in available manpower due to vacation leaves, illnesses and injuries in addition to a lack of suitable vehicles.[199]

The third possibility cited was that the design of the PILOT program model was flawed and not capable of accomplishing reductions in crime.[200] The reasons identified to explain the failure of the model were twofold. First, that the information provided by the predictive analysis models used might not provide any better information than existing, conventional crime analysis methods.[201] Secondly, no specific, standardized treatment interventions were established, which left area commanders latitude in deciding what, and how much treatment to apply (treatment and dosage).[202] Treatments varied between the commands in terms of hours applied to PILOT (dosage), and specific actions taken by officers assigned to the PILOT project As a result, the treatment and dosage may not have been applied in the right manner or frequency to have an impact. A lack of a standard treatment model in the experimental and control groups permits a second experimental variable, making it impossible to determine if any observed variations in crime are caused by the treatment, or the difference between the predictive analysis or standard crime mapping.

The variation in crime over the total experimental period was not significantly different from the natural variation that occurred in the years prior to the experiment.[203]

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[196] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

[197] Ibid.

[198] Ibid.

[199] Ibid.

[200] Ibid.

[201] Ibid.

[202] Ibid.

[203] Ibid.

Overall, the Rand study could not attribute causation, nor could it detect the true impact of PILOT.[204]

This author's examination of the year over year crime rates obtained from data publicly available on the Shreveport Police Department website did not reveal anything that points definitively to what, if any, impact the Shreveport predictive policing experiment may have had. This finding appears to affirm the conclusions of the more detailed and academically robust Rand study.

As illustrated by Figure 12, during 2012, which includes the experimental period, no consistent trend occurred when comparing crime totals in the experimental districts with the same numbers in the control districts. In the experimental districts, the number of commercial thefts, residential thefts, and thefts from automobiles were less than in the control districts, but the number of residential and commercial burglaries, as well as auto thefts, was greater in the experimental districts than in the control.

When comparing the experimental districts with the control districts over a multi-year period (Figure 13), the same inconsistency is observed: The number of crimes is not consistently greater or fewer in any category from district to district.

This experiment occurred during a multi-year time period in which property crime and Part 1 crime was generally trending downward (Figures 11 and 14), with the exception of 2012, the year of the experiment, during which both property crime and Part 1 crime exceeded the totals during the previous year (2011) and the following year (2013).

The lack of a consistent trend and the inability to isolate the impact of the experiment from other variables including, but not limited to, a citywide (and nationwide) downward trend in crime, unknown environmental factors, etc., have made it difficult, if not impossible, for this research to discern the impact of Shreveport's predictive policing experiment, or to attribute causation to any increase or decrease in a particular crime category in any particular district.

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[204] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

In spite of the inconclusive impact of the PILOT experiment on crime, other beneficial impacts were observed during the experimental period. Shreveport police officers reported improved community relations as a result of the increased communication with the public during PILOT patrols.[205] Over the course of the experiment, the public "became more willing to provide additional information or call in with tips."[206]

Officers reported that the so-called predictive maps were useful in planning where to focus their policing strategies in terms of when and where their activities should be focused. One district commander observed, however, that since the predictive algorithm was only generated once per month, the map identified grid squares at risk of property crime over the course of an entire month, rather than a more specific time frame;[207] rendering the map relatively similar to historical crime maps used in hot spots policing. Regardless of the predictive value of the map, Shreveport officers stated that the benefit was in having a focus for directed patrols and other interventions. The increased public interaction and map-driven interventions resulted in the development of improved actionable intelligence that officers used to disrupt and inconvenience criminals in their patrol areas.[208]

Police executives considering investing in a predictive policing program should give the Shreveport experiment careful consideration. The experiment used sound research methods and is the only randomized controlled trial that has been published as of this writing. In spite of the experiment's rigor, the inconclusive results and the questionable impact on crime in Shreveport indicate that further research is needed before the value of predictive policing can be proven.
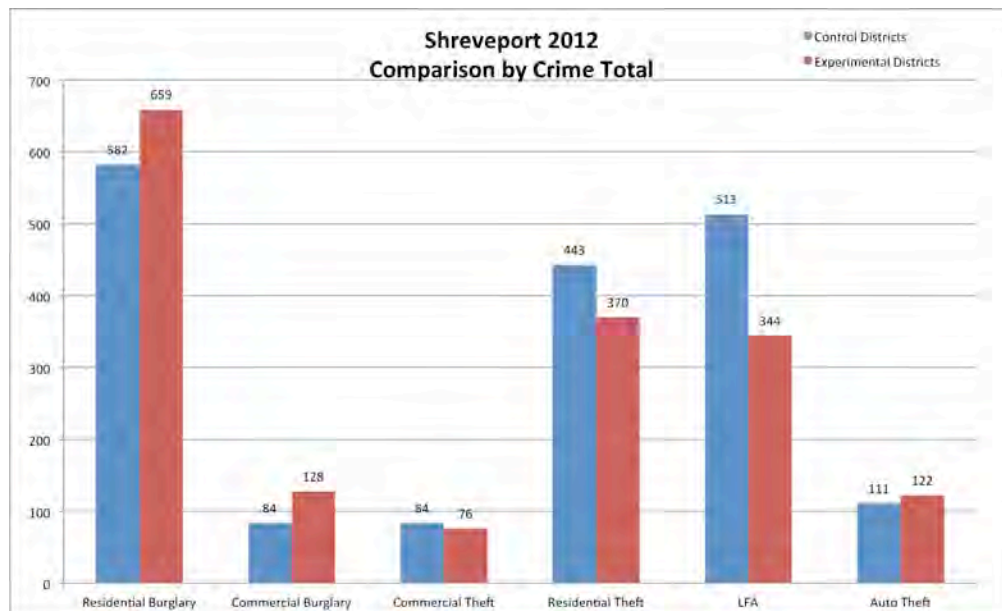
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[205] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.
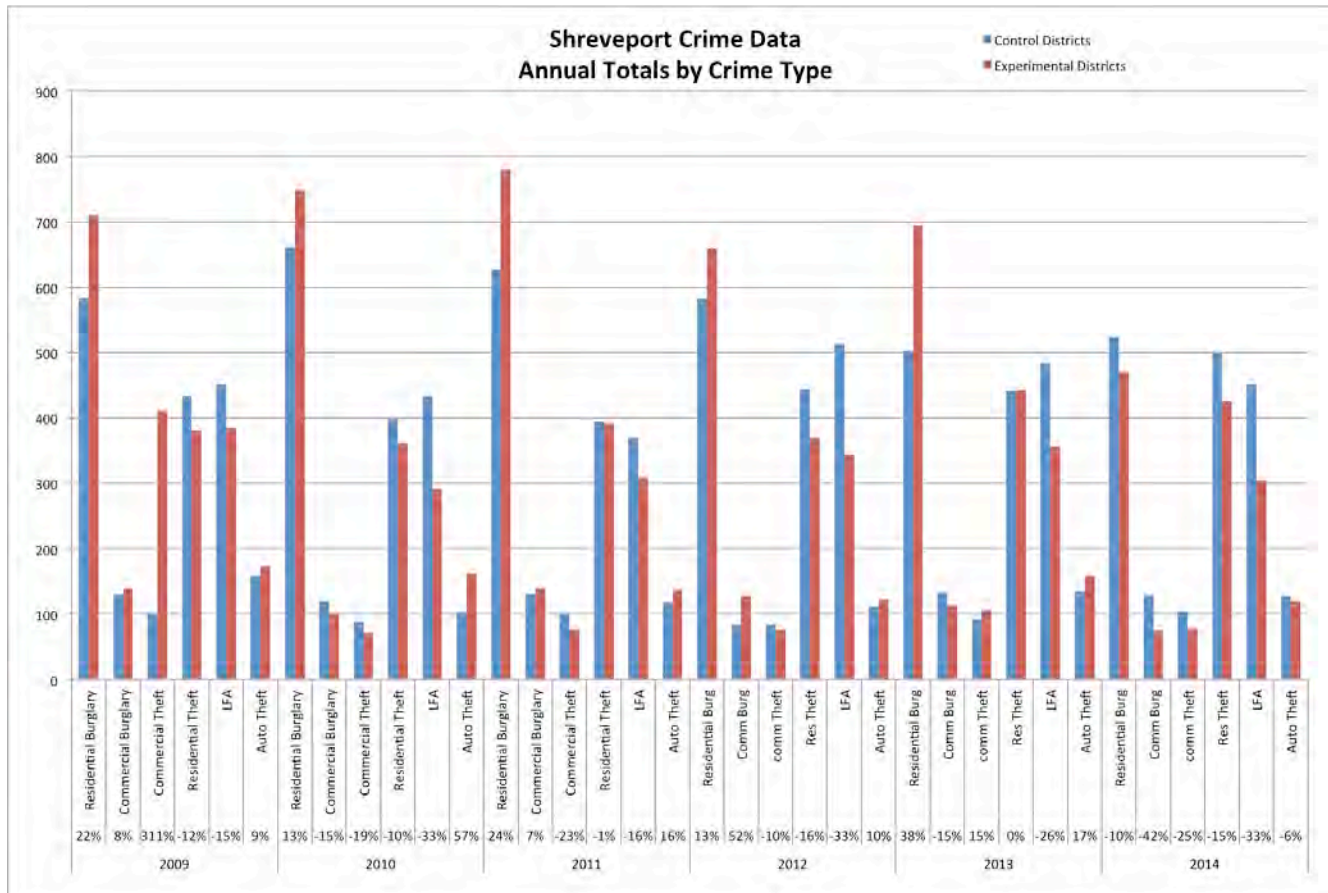
[206] Ibid.

[207] Ibid

[208] Ibid.

Figure 12.   Shreveport 2012 Comparison by Crime Total

Source: "Comprehensive Annual Financial Report," accessed September 7, 2015, https://www.shreveportla.gov/Archive.aspx?AMID=42.

Figure 13.   Shreveport Crime Data Annual Totals by Crime Type

Figure 14.   Citywide Property Crime Index
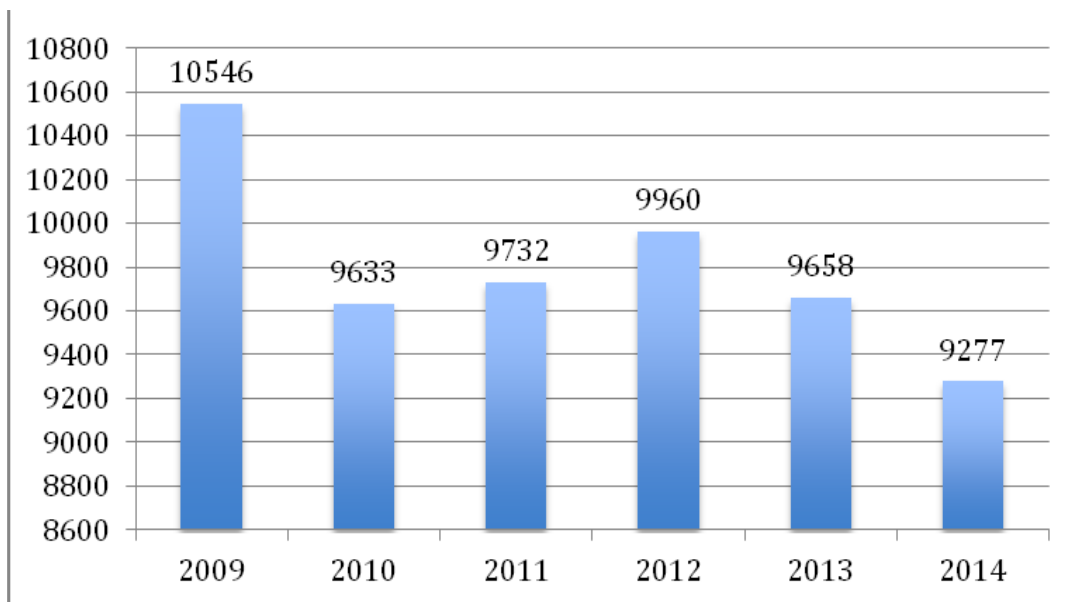
Source: "Comprehensive Annual Financial Report," accessed September 7, 2015, https://www.shreveportla.gov/Archive.aspx?AMID=42.

VIII. RECOMMENDATIONS/CONCLUSIONS

A.   CONCLUSIONS

This thesis provides law enforcement executives and policy makers with objective research on the effectiveness of predictive analysis in reducing crime and to provide recommendations for those evaluating whether to invest time and resources into a predictive policing program. Law enforcement leaders seek effective crime control strategies, because if crime can be reduced, then community safety and resiliency are improved. This thesis also asserts that reducing crime improves community resilience, therefore improving homeland security. By effectively combating crime in their communities, police chiefs will have the opportunity to reallocate resources towards other homeland security priorities.

Implementing a new crime control strategy requires a commitment to design and implement the strategy, invest money in suitable equipment and software, train personnel, monitor and evaluate results, and adjust the strategy as appropriate. Such a large investment should not be undertaken without knowing that the practice being invested in has been validated and will produce the expected result. At present, predictive analysis and predictive policing programs have not been widely studied from an objective, scientific perspective. While initial experiences by the agencies that have either fully implemented or experimented with predictive policing seem to be positive, predictive policing's impact on crime has yet to be definitively determined.

The author's primary intent in conducting this research is to answer whether predictive policing is an effective crime control practice that can contribute to improved homeland security. In approaching this research, the extant literature on the subject was explored to evaluate the current body of knowledge on predictive policing. Further review was conducted to understand and inform the reader about the theoretical foundations behind predictive policing, and the use of predictive analysis in other fields outside of law enforcement. The review revealed that predictive policing takes many

different forms, and that a number of different models and methodologies are within the broader definition of predictive policing.

In subsequent chapters, case studies of predictive policing experiments in Santa Cruz, California; Shreveport, Louisiana; and Atlanta, Georgia were included as illustrations of various efforts to put predictive policing theory into practice. Each city used a different approach when creating their predictive policing models. Evaluation of crime data for each of the case cities in this research failed to reveal a conclusive answer to the primary research question, in spite of claims from vendors and department representatives to the contrary. As previously discussed in this thesis, one of the limitations to this research is the potential for different outcomes due to differences in methodologies used for this thesis as compared to the methodologies used by the case cities and/or their vendors.

One finding of this research is that predictive policing can clearly be broken down into two components, (1) analysis of data to make crime predictions in terms of time and space, and (2) the use of the predictions by the police to conduct interventions in the specified locations. As a result, any objective study of predictive policing should not only include evaluating the predictive efficacy of whatever algorithm is being used, but also the treatment and dosage applied by the police is a variable that should be studied as well.

This thesis defined effectiveness as improvement in quantitative measures of crime following the application of predictive analysis. As the case studies demonstrate, a mixed bag of improvement and worsening of crime was associated with the various predictive policing experiments studied. What did not emerge from this study was a clear relationship between the quantitative measure of crime and predictive policing. Even in those circumstances in which a reduction in crime coincided with the application of predictive policing, the reduction in crime could not be more definitively connected to predictive policing than any other variable. What is most apparent from this research is that further study is needed to inform decision making fully in this area.

Any evaluation of the effectiveness of predictive policing should include a discussion on how effectiveness is measured. The majority of the literature on the subject

measures success by evaluating how quantity of crime responds to the application of predictive policing. Research into predictive policing should include an evaluation of whether it is an appropriate metric by which to measure success. As demonstrated in the literature, and the evaluation of the case study data for this thesis, the relationship between crime numbers and predictive policing is still unclear. In spite of this ambiguity, some qualitative evidence indicated a positive outcome from predictive policing.

In the Shreveport study, it was noted that officers reported improved community relations and that the public became more cooperative in providing information to the police.[209] The study also noted that officers found the predictive maps generated by the experiment useful in providing a focus for directed patrol activity and other interventions within their respective districts.[210] These beneficial impacts, while anecdotal, did not correlate with either a decrease or increase in the amount of crime.

A future consideration for evaluating predictive policing might include a qualitative metric to evaluate community impacts, such as fear and resilience. The impact of fear on community resilience and homeland security has been established. Crime and fear of criminal activity consumes police resources. If it can be established that predictive policing can reduce community fear, the practice can therefore improve homeland security. If reduction of fear is to be the desired goal of predictive policing, then a method to measure fear, such as community surveys, must be established. The Massachusetts State Police (MSP) incorporated community surveys as part of its evaluation of a crime reduction strategy that it introduced in the city of Springfield. The MSP experience in Springfield serves as an example of how predictive policing programs might be evaluated.

In 2009, the Massachusetts State Police partnered with the Springfield Police Department and piloted Counter Criminal Continuum (C3) policing in an effort to combat gang violence in the North End of Springfield. C3 policing adapts counterinsurgency (COIN) tactics to build community relationships and deprive organized gangs of the

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[209] Hunt, Saunders, and Hollywood, *Evaluation of the Shreveport Predictive Policing Experiment*.

[210] Ibid.

opportunity to conduct criminal activity unhindered. Analysis of the Springfield initiative indicated that C3 policing improved conditions in Springfield's North End, and the MSP is considering expanding C3 policing into other jurisdictions.[211] Officers conducted foot patrols, making contact with business owners and residents, opening lines of communication and building trust. The desired end state of the Springfield C3 initiative was to disrupt gang activity, deny the opportunity for them to operate in the open unchallenged, and encourage citizens to report criminal activity to the police.[212]

A number of metrics were used to measure the effectiveness of the C3 policing strategy in Springfield, which included crime-related medical calls, economic indicators, truancy, criminal behavior in schools, housing conditions, littering, graffiti, crime reports, and community perception surveys. According to Bruce Hiorns, a captain with the MSP, "data regarding calls for service, reported crime, litter, graffiti, and school disciplinary reports suggested a positive impact."[213] The initiative also measured indices of community health, such as home values, new business registrations, and captured residents feedback on the impact of C3 by the use of community surveys.[214]

An analysis of the Springfield C3 program underscores the relationship between fear of crime and community resilience. It has been previously demonstrated that the level of citizens' fear of crime is not necessarily associated with actual crime levels. Fear can be driven by factors, such as graffiti, litter, noise, and other quality of life problems that contribute to a person's increased perceptions of fear.[215] Fear has been shown to weaken the community structures that help maintain resilience.[216] Those measuring the effectiveness of predictive policing, or any other crime control strategy for that matter,

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[211] Bruce Hiorns, *Analysis of C3 Policing in Springfield's North End, and Strategy for Further Implementation* (Northampton, MA: The Commonwealth of Massachusetts Department of State Police, 2013).

[212] Bruce Hiorns, "Analysis of C3 Counterinsurgency-Inspired Policing and the Flip Side of the Coin" (master's thesis, Naval Postgraduate School, 2014).

[213] Hiorns, *Analysis of C3 Policing in Springfield's North End, and Strategy for Further Implementation.*

[214] Hiorns, "Analysis of C3 Counterinsurgency-Inspired Policing and the Flip Side of the Coin"; Hiorns, *Analysis of C3 Policing in Springfield's North End, and Strategy for Further Implementation.*

[215] Cordner, *Reducing Fear of Crime: Strategies for Police.*

[216] Hiorns, "Analysis of C3 Counterinsurgency-Inspired Policing and the Flip Side of the Coin."

should consider a methodology that includes a measurement of fear in a community, rather than just quantitative crime numbers.

B.   RECOMMENDATIONS

Based on the research and findings for this thesis, the following recommendations are presented to guide future researchers studying the efficacy of predictive policing:

- Randomized controlled trials should be conducted by independent entities not having a proprietary interest in the outcome.

- Conceive of metrics to measure effectiveness including, but not limited to measuring quantitative crime data. These metrics should include comparing interventions with outcomes, qualitative assessments of fear, and the use of community surveys to capture data indicative of the state of a community's resilience.

- Conceive of a method to study the impact of predictive policing in isolation from other factors that may also be impacting crime levels at the same time.

Law enforcement executives considering investing in a predictive policing strategy should be aware that predictive policing is not a one-size-fits-all solution, nor has its efficacy been validated. Like many other crime prevention programs, some crimes will respond better to a particular intervention than others. Hot spots policing, which has been validated through extensive study by researchers like Anthony Braga, is an alternative to predictive policing that might be more worthy of consideration while the jury is still out on predictive policing. Regardless of what method is selected to use data to drive crime reduction strategies, police leaders must always be mindful of the fact that data analysis alone will not prevent crime. The police executive must have specific interventions in mind for officers to apply in the field. Do not forget that the delivery of service, and the success of any crime control strategy is dependent on the actions of police officers in the community in direct contact with its citizens. Police officers are the most visible representatives of government in local communities, and as such, the effectiveness of their crime control strategies has a direct impact on community fear and resilience, and therefore, homeland security.

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LIST OF REFERENCES

Airport Council International. "ACI World Releases Preliminary World Airport Traffic and Rankings for 2014—DXB Becomes Busiest Airport for International Passenger Traffic." Accessed September 7, 2015. http://www.aci.aero/News/ Releases/Most-Recent/2015/03/26/ACI--World-releases-preliminary-world- airport-traffic-and-rankings-for-2014--DXB-becomes-busiest-airport-for- international-passenger-traffic-.

Alexander, Dean C., and Terry Mors. "Best Practices in Identifying Terrorists during Traffic Stops and on Calls for Service." *Crime and Justice International* 23, no. 99 (2007): 4–12.

Atlanta Police Department. "Atlanta Police Department-Crime Data Downloads." February 21, 2015. http://www.atlantapd.org/crimedatadownloads.aspx.

———. *Atlanta Police Department 2010–2014, An Overview*. Atlanta, GA: Atlanta Police Department, n.d.

Bachner, Jennifer. "Predictive Policing: Preventing Crime with Data and Analytics." IBM Center for the Business of Government, 2013. http://www.businessof government.org/report/predictive-policing-preventing-crime-data-and-analytics.

Ball, John E. "Rethinking Intelligence to Integrate Counterterrorism into the Local Law Enforcement Mission." Master's thesis, Naval Postgraduate School, 2007. http://calhoun.nps.edu/public/handle/10945/3656.

Beck, Charlie, and Colleen McCue. "Predictive Policing: What Can We Learn from Wal- Mart and Amazon about Fighting Crime in a Recession?" *Police Chief Magazine*, November 2009.

Benigni, Matthew, and Reinhard Furrer. *Periodic Spatio-Temporal Improvised Explosive Device Attack Pattern Analysis*. (Technical report Mcs-04-08). Golden, CO: Colorado School of Mines, 2008.

Bennett Jr., John A. "Combating Terrorism Within Local Policing through Crime Reduction: Using Real-Time, Situational Awareness Within A Distributed Common Operating Picture to Combat All Crime and Terrorism–V2i2sion Process and Safecop Pilot Project." 2013. http://calhoun.nps.edu/public/ handle/10945/32793.

Braga, Anthony. "The Effects of Hot Spots Policing on Crime." The Campbell Collaboration, June 27, 2012. http://campbellcollaboration.org/lib/project/24/.

Braga, Anthony A. "Hot Spots Policing and Crime Prevention: A Systematic Review of Randomized Controlled Trials." *Journal of Experimental Criminology* 1, no. 3 (September 1, 2005): 317–42. doi:10.1007/s11292-005-8133-z.

Braga, Anthony Allan, and David Weisburd. *Policing Problem Places: Crime Hot Spots and Effective Prevention*. Oxford: Oxford University Press, 2010.

Burke, Kerry, Edgar Sandoval, and Jonathan Lemire. "NYPD Crime Statistics Say New York City Is Safer, But Many Worry Economy Is Spurring Crime Surge." *New York Daily News*, May 26, 2009. http://www.nydailynews.com/news/crime/nypd-crime-statistics-new-york-city-safer-worry-economy-sparking-crime-surge-article-1.374787.

California Department of Corrections and Rehabilitation. *Fact Sheet: Three-Judge Panel and California Inmate Population Reduction*. San Pablo, CA: California Department of Corrections and Rehabilitation, 2011.

———. "Public Safety Realignment." Accessed January 27, 2015. http://www.cdcr. ca.gov/realignment/.

Caplan, Joel M., and Leslie W. Kennedy. *Risk Terrain Modeling Manual: Theoretical Framework and Technical Steps of Spatial Risk Assessment for Crime Analysis*. Newark, NJ: Rutgers Center on Public Security, 2010.

Chen, Hsinchun, Roger HL Chiang, and Veda C. Storey. "Business Intelligence and Analytics: From Big Data to Big Impact." *MIS Quarterly* 36, no. 4 (2012). http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=02767783&AN=83466038&h=7OlQMXoL1qrJ31m3%2FMaAtQ0gADgZ7JWseTKbP14GdBSeWYAE4xXJsD3ON9pvSGHFSHfOx9tniPXX%2BMaOgEVTkQ%3D%3D&crl=c.

City of Santa Cruz. "Annual Statistics." Accessed January 13, 2015. http://www.cityofsantacruz.com/departments/police/crime-statistics/annual-statistics.

———. "Department Structure and Facts." Accessed January 13, 2015. http://www.cityofsantacruz.com/departments/police/about-us/department-facts.

City of Shreveport, LA. "Comprehensive Annual Financial Report." Accessed September 7, 2015. https://www.shreveportla.gov/Archive.aspx?AMID=42.

Cohen, Lawrence E., and Marcus Felson. "Social Change and Crime Rate Trends: A Routine Activity Approach." *American Sociological Review* 44, no. 4 (August 1, 1979): 588–608. doi:10.2307/2094589.`

Cordner, Gary. *Reducing Fear of Crime: Strategies for Police*. Washington, DC: U.S. Department of Justice, Office of Community Oriented Policing Services, 2010.

Crask, Melvin R. "A Simulation Model of Patronage Behavior within Shopping Centers." *Decision Sciences* 10, no. 1 (January 1979): 1–15.

Department of Homeland Security. "Resilience." Accessed December 27, 2014. http://www.dhs.gov/topic/resilience.

Etchison, J. C. "Theories of Crime Causation." *Policy Studies Journal* 3, no. 1 (September 1974): 7–12.

Farrell, Graham, and William Sousa. "Repeat Victimization and Hot Spots: The Overlap and Its Implications for Crime Control and Problem-Orientated Policing." *Crime Prevention Studies* 12 (2001): 221–40.

FBI. "Crime in the U.S." Accessed December 28, 2014. http://www.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s.

———. "Summary of the Uniform Crime Reporting Program." 2010. https://www.fbi.gov/about-us/cjis/ucr/leoka/leoka-2010/aboutucrmain.

Ferguson, Andrew Guthrie. "Predictive Policing and Reasonable Suspicion." *Emory Law Journal* 62 (2012): 259–325.

Focus on Results Atlanta. "FOR Atlanta—City Performance Metrics." Accessed February 16, 2015. http://foratlanta.github.io/charts/atlanta-police-department.html.

Globalization and World Cities (GaWC) Research Network. "GaWC—The World According to GaWC 2012." Accessed September 7, 2015. http://www.lboro.ac.uk/gawc/world2012t.html.

Groff, Elizabeth R., and Nancy G. La Vigne. "Forecasting the Future of Predictive Crime Mapping." *Crime Prevention Studies* 13 (2002): 29–58.

Harris, Kamala D. *Crime in California 2010*. Sacramento, CA: Office of the Attorney General, California Department of Justice, 2011.

Hart, Timothy C., and Paul A. Zandbergen. "Effects of Data Quality on Predictive Hotspot Mapping." National Criminal Justice Reference Service, 2012. https://www.ncjrs.gov/pdffiles1/nij/grants/239861.pdf.

Hiorns, Bruce. "Analysis of C3 Counterinsurgency-Inspired Policing and the Flip Side of the Coin." Master's thesis, Naval Postgraduate School, 2014.

———. *Analysis of C3 Policing in Springfield's North End, and Strategy for Further Implementation*. Northampton, MA: The Commonwealth of Massachusetts Department of State Police, 2013.

Hunt, Priscillia, Jessica Saunders, and John S. Hollywood. *Evaluation of the Shreveport Predictive Policing Experiment*. Santa Monica, CA: RAND Corporation, 2014. http://www.rand.org/pubs/research_reports/RR531.html.

Jordan, Ferenc. "Predicting Target Selection by Terrorists: A Network Analysis of the 2005 London Underground Attacks." *International Journal of Critical Infrastructures* 4, no. 1 (January 1, 2008): 206–14. doi:10.1504/IJCIS.2008.016101.

Kebbell, Mark R., and Louise Porter. "An Intelligence Assessment Framework for Identifying Individuals at Risk of Committing Acts of Violent Extremism against the West." *Security Journal* 25, no. 3 (2012): 212–28.

Koper, Christopher S. "Just Enough Police Presence: Reducing Crime and Disorderly Behavior by Optimizing Patrol Time in Crime Hot Spots." *Justice Quarterly* 12, no. 4 (December 1, 1995): 649–72. doi:10.1080/07418829500096231.

Land, Collette. "The Power of Predictive Analytics." *Credit Management*, December 2, 2006, 12–15.

Lanier, Cathy L. "Preventing Terror Attacks in the Homeland a New Mission for State and Local Police." Master's thesis, Naval Postgraduate School, 2005. http://calhoun.nps.edu/public/handle/10945/1957.

Males, Mike, and Brian Goldstein. *California's 58 Crime Rates: Realignment and Crime in 2012*. San Francisco, CA: Center on Juvenile and Criminal Justice, January 2014.

Marano, Hara Estroff. "Our Brain's Negative Bias." *Psychology Today*, June 20, 2003. http://www.psychologytoday.com/articles/200306/our-brains-negative-bias.

Mason, J. Barry. "Retail Market Area Shape and Structure: Problems and Prospects." *Advances in Consumer Research* 2, no. 1 (January 1975): 173.

McCue, Colleen. *Data Mining and Predictive Analysis: Intelligence Gathering and Crime Analysis*. Oxford: Butterworth-Heinemann, 2006.

McCue, Colleen, and Andre Parker. "Connecting the Dots: Data Mining and Predictive Analytics in Law Enforcement and Intelligence Analysis." *Police Chief* 70, no. 10 (2003): 115–24.

Merriam-Webster.com. "Data Mining." Accessed November 2, 2013. http://www.merriam-webster.com/dictionary/data mining.

Metro Atlanta Chamber. "Fortune 500 and Fortune 1000 Headquarters in Atlanta." Accessed September 7, 2015. http://www.metroatlantachamber.com/business/data/fortune-500-1000-hq.

Mohler, George O., Martin B. Short, P. Jeffrey Brantingham, Frederic P. Schoenberg, and George E. Tita. "Self-Exciting Point Process Modeling of Crime." *Journal of the American Statistical Association* 106, no. 493 (March 1, 2011): 100–108. doi:10.1198/jasa.2011.ap09546.

Moore, Mark H., and Anthony Braga. *The "Bottom Line of Policing."* Washington, DC: Police Executive Research Forum (PERF), 2003.

National Institute of Justice. "Predictive Policing." Accessed October 19, 2013. http://www.nij.gov/topics/law-enforcement/strategies/predictive-policing/welcome.htm.

New York Times. "Sir Robert Peel's Nine Principles of Policing." April 15, 2014. http://www.nytimes.com/2014/04/16/nyregion/sir-robert-peels-nine-principles-of-policing.html.

Pearsall, Beth. "Predictive Policing: The Future of Law Enforcement." *National Institute of Justice Journal* 266 (2010): 16–19.

Perry, Walter L., Brian McInnis, Carter C. Price, Susan Smith, and John S. Hollywood. "Predictive Policing: The Role of Crime Forecasting in Law Enforcement Operations." Product Page, 2013. http://www.rand.org/pubs/research_reports/RR233.html.

"Predictive Analytics-Police Use Analytics to Reduce Crime." You Tube video, 0:33. Posted by IBM. Published March 27, 2012. http://youtu.be/_ZyU6po_E74.

PredPol. "Predict Crime." Accessed September 13, 2015. https://www.predpol.com/.

———. "PredPol Atlanta Crime Rate Reduced 19%." Accessed February 16, 2015. http://www.predpol.com/predpol-atlanta/.

Ratcliffe, Jerry. *Intelligence-Led Policing*. London and New York: Willan Publishing, 2008.

Ratcliffe, Jerry H., Joel Caplan, John E. Hollywood, Steven Schuetz, and Susan Reno. "Predictive Analytics: Theories and Practices." Paper presented at the 120th International Association of Chiefs of Police Conference, Philadelphia, PA, October 21, 2013.

Schoenberg, Frederic Paik. "Introduction to Point Processes." UCLA Department of Statistics, 2011. http://escholarship.org/uc/item/4k35g3w6.pdf.

Shreveport Police Department. *Shreveport Police Department 2014 Annual Crime Report*. Shreveport, LA: Shreveport Police Department, 2014.

———. *Shreveport Police Department 2014 Crime Statistics*. Shreveport, LA: Shreveport Police Department, 2015.

Skogan, Wesley G., and Michael G. Maxfield. *Coping with Crime: Individual and Neighborhood Reactions*. Thousand Oaks, CA: Sage Publications, 1981. https://www.ncjrs.gov/App/Publications/abstract.aspx?ID=78899.

St. John, Paige. "Early Jail Releases Have Surged since California's Prison Realignment." *Los Angeles Times*, August 16, 2014. http://www. latimes.com/local/crime/la-me-ff-early-release-20140817-story.html#page=1.

Stover, Christopher. "Hawkes Process." *MathWorld--A Wolfram Web Resource*. Accessed December 14, 2014. http://mathworld.wolframcom/Hawkes Process.html.

Taylor, Ralph B., and Margaret Hale. "Testing Alternative Models of Fear of Crime." *Journal of Criminal Law and Criminology* 77, no. 1 (1986): 151–89.

Telep, Cody W. *Police Interventions to Reduce Violent Crime: A Review of Rigorous Research*. Fairfax, VA: Center for Evidence-Based Crime Policy, George Mason University, 2009.

Turner, George, Dr. Jeff Brantingham, and Dr. George Mohler. "Predictive Policing in Action in Atlanta, Georgia." *The Police Chief*, May 5, 2014. http://www.police chiefmagazine.org/magazine/ index.cfm?fuseaction=display&issue_id=52014&category_ID=4.

U.S. Census Bureau. "American FactFinder." Accessed February 21, 2015. http://fact finder.census.gov/faces/nav/jsf/pages/index.xhtml.

———. "American FactFinder—Results." Accessed January 13, 2015. http://factfinder. census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk.

Uchida, Craig D. *A National Discussion of Predictive Policing: Defining Our Terms and Mapping Successful Implementation Strategies*. Washington, DC: National Institute of Justice, 2009.

———. "Encyclopedia of Criminology and Criminal Justice." Edited by Gerben Bruinsma and David Weisburd, 2014. http://link.springer.com/10.1007/978-1-4614-5690-2.

UK Parliament. "Metropolitan Police." Accessed December 27, 2014. http://www. parliament.uk/about/living-heritage/transformingsociety/laworder/policeprisons/ overview/metropolitanpolice/.

United States Census Bureau. "2010 Census Gazetteer File-Places-California." Accessed January 12, 2014. http://www.census.gov/geo/maps-data/data/docs/gazetteer/2010_place_list_06.txt.

———. "Atlanta (city) QuickFacts from the U.S. Census Bureau." Accessed February 16, 2015. http://quickfacts.census.gov/qfd/states/13/1304000.html.

University of California Santa Cruz. "UC Santa Cruz Facts." Accessed January 27, 2015. http://admissions.ucsc.edu/apply/parents-and-guardians/prospective-students/facts.html.

Vlahos, James. "The Department of Pre-Crime." *Scientific American* 306, no. 1 (2012): 62–67. doi:10.1038/scientificamerican0112-62.

Weisburd, David, and Tom McEwen. *Crime Mapping and Crime Prevention*. Monsey, NY: Criminal Justice Press, 1998.

Whiting, Rick. "Predict the Future-Or Try, Anyway." *Information Week*, May 29, 2006. ProQuest.

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